AVIATION AND THE EMERGING USE OF BIOFUELS

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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AVIATION AND THE EMERGING USE OF BIOFUELS

THURSDAY, MARCH 26, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Gabrielle Giffords [Chairwoman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE & AERONAUTICS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

Aviation and the Emerging Use of Biofuels

March 26, 2009
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. Jaiwon Shin
Associate Administrator
Aeronautics Research Mission Directorate
NASA

Dr. Lourdes Maurice
Environmental Lead
Commercial Aviation Alternative Fuels Initiative (CAAFI)

Dr. Alan H. Epstein
Vice President
Technology and Environment
Pratt & Whitney
United Technologies Corporation

Mr. Bill Glover
Managing Director
Environmental Strategy
The Boeing Company

Mr. Holden Shannon
Senior Vice President
Global Real Estate and Security
Continental Airlines

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HEARING CHARTER

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Aviation and the Emerging Use of Biofuels

THURSDAY, MARCH 26, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

The House Committee on Science and Technology's Subcommittee on Space and Aeronautics is convening a hearing to review the status of federal and industry research and development (R&D) efforts to develop and demonstrate the safe and cost-effective use of biofuels in civil aviation. The hearing will focus on the following questions and issues:

- What research is needed to determine the optimal characteristics of both aircraft engine technologies and biofuels to minimize harmful emissions while maintaining aircraft safety and reliability and maximizing performance?
- What are the most realistic aviation biofuel options over the long-term, and what will be required to achieve widespread use of biofuels in aviation?
- What steps, if any, is the Federal Government taking to assess the viability of biofuels for aviation or to facilitate their widespread use in aviation?
- What are the results of the recently completed aviation biofuels demonstrations?

II. Witnesses

Dr. Jaiwon Shin
Associate Administrator
Aeronautics Research Mission Directorate
National Aeronautics and Space Administration

Dr. Lourdes Q. Maurice
Chief Scientist
Federal Aviation Administration
Environmental Lead for the Commercial Aviation Alternative Fuels Initiative

Dr. Alan H. Epstein
Vice President, Technology and Environment
Pratt & Whitney
United Technologies Corporation

Mr. Billy M. Glover
Managing Director, Environmental Strategy
Boeing Commercial Airplane Company

Mr. Holden E. Shannon
Senior Vice President of Global Real Estate and Security
Continental Airlines

III. Overview

The convergence of high fuel prices with possible caps on harmful aircraft engine emissions has encouraged the aviation community to investigate alternatives to petroleum-based jet fuels that would be safe and cost-effective—both to use and produce. In 2006, for the first time in history, fuel became the single largest component of U.S. airline operating cost. According to the Air Transport Association (ATA), while consumption by commercial aircraft has stayed steady over a seven year period at about 20 billion gallons per year, jet fuel expenses have more than doubled over that same period. The aviation industry has achieved substantial improvements in fuel efficiency since the introduction of commercial jet aircraft in the

1960s through fleet modernization, air traffic management improvements and operational changes. However, despite such improvements, expectations of increased fuel consumption from projected growth in air travel and the possibility of higher fuel prices are forcing the aviation industry to try to reduce its reliance on fossil fuels and find alternative sources of supply.

So far, alternative fuels being considered for aviation include synthetic fuels, such as those produced using a process called Fischer-Tropsch, and a number of biofuels. While synthetic fuels made from coal, natural gas and other hydrocarbon feedstock are attractive because they can be easily integrated into existing aircraft systems, such fuels do not help address climate issues and as such are viewed by some as only near-term alternatives. In contrast, biofuels produced from a wide variety of plant material are characterized as "carbon neutral" and thus may help mitigate the impact of aviation on the environment. First-generation biofuels, commonly made from fermented sugars from wheat or corn; soy beans; and sunflower seeds are generally unsuitable for aviation jet fuel. If biofuels are to become successful in commercial aviation use, they will need to be high in energy, safe to use, capable of working well in sub-zero temperatures at high altitudes, cost-efficient to make, suitable for production in large quantities, and capable of burning cleanly.

Of late, there has been significant activity in the development and testing of biofuels for aviation. U.S. research in the application of biofuels for aviation is being conducted by the National Aeronautics and Space Administration (NASA); the Department of Defense (DOD); a consortium of the Federal Aviation Administration (FAA), airlines and aircraft manufacturers; and other partnerships. The airline industry views the primary benefit of using biofuels as being the enhancement of the industry's ability to reduce greenhouse gases throughout the fuels' entire life cycle.

Recent tests using various biofuel blends, including well-publicized demonstrations by several commercial partnerships, have created high expectations, both in this country and abroad. Testimony at this hearing should provide the Subcommittee with an assessment of what research and tests are being done, who is doing it, what further research is needed, and whether a timeframe for the widespread availability of biofuel for aviation can be projected.

IV. Potential Hearing Issues

The following are some of the potential issues that may be raised at the hearing:

- *What research is being conducted to validate the projected benefits of using biofuels in aviation with regards to their ability to reduce aircraft engine emissions?*
- *Is there an overall "roadmap" for conducting aviation biofuel research? Is the research performed by the Federal Government aligned with that conducted by the private sector? Are research results available to all?*
- *Can the development readiness of emerging biofuels be commonly characterized and measured using standard metrics?*
- *What has been learned so far from partnership demonstrations using biofuels? Are additional demonstrations planned?*
- *What research is being planned or conducted to determine the impact long-term and widespread biofuel use may have on aircraft safety, and engine performance/maintainability/reliability? Is more research needed? In what areas?*
- *Has the recent downturn in fuel prices and in the Nation's economy lessened the urgency of developing biofuels for civil aviation use?*
- *What key challenges need to be resolved before widespread use of biofuels in civil aviation can occur and what role should the Federal Government play?*

V. Background

Issues Associated with Biofuels in Aviation

Before biofuels can be used in civil aviation, a number of issues will need to be addressed. While not exhaustive, the following list of R&D tasks identified by NASA is illustrative of the scope of research that may be needed before widespread use of biofuels in the aviation sector can occur:

- Understanding combustion behavior for the new fuels and demonstrating long-term engine combustor performance and developing predictive models for combustor performance to enable low emission combustor design using biofuels.

- Understanding the emission characteristics of biofuels, in particular understanding the effect of biofuel constituents on the emission characteristics so that the biofuel can be optimized for reducing emissions in gas turbine engines.
- Demonstrating the biofuels' desired thermal stability under a range of temperatures encompassing high temperatures to freezing, lubricity, and no seal leakage.
- Demonstrating long-term performance of engines.
- Demonstrating long-term durability of engine components.

The setting of fuel specifications is another significant issue recognized by the aviation industry. As indicated in an *Alternative Aviation Fuels Q&A* by the Air Transport Association (ATA) on their website, all aircraft and engines in the United States must be approved (technically, "certificated") by the Federal Aviation Administration (FAA) for use. To quote the ATA website's Q&A:

> *"FAA approval is specific to the fuel that is used and the particular aircraft and/or engine type. Any deviation from the FAA approval certificate requires extensive FAA re-evaluation and approval."*

FAA's role is in certifying aircraft, not in the fuel. However, FAA's certification has a tie-in to the type of fuel utilized. As stated in ATA's Q&A:

> *"The FAA certifies aircraft and engines. An element of this certification is a listing of the operational requirements and limitations for the specific equipment that is being certified, which includes identification of the type of jet fuel approved for use in that equipment. Therefore, the FAA specifies what type of fuel is to be used but does not certify the jet fuel itself. Separately, airline fueling manuals, with which airlines must comply by law, are based upon the jet fuel recognized by the FAA. Before FAA identifies the fuel appropriate for specific equipment, and before airlines can include the fuel requirements in fueling manuals, the fuel already has been determined to meet the specifications necessary to be safely used in the relevant equipment. In the case of jet fuel, the applicable standard (also referred to as a "specification") is controlled by ASTM International, an organization devoted to the development and management of standards for a wide range of industrial products and processes. It is this specification that is included in FAA product approvals and required air carrier manuals. Periodically, through ASTM's established procedures, the specification is updated and revised by a specialized committee of experts. Proposed changes to the specification are carefully considered, and a formal balloting process is conducted to secure consensus before any revision is accepted. Fuels produced from alternative sources must complete this rigorous vetting process to establish that they meet the specification requirements to be safely used as jet fuel."*

Alternative fuels such as biofuels will need to go through this vetting process before they can be used in civil aviation. The ATA website's Q&A further states:

> *"In light of this regulatory arrangement and the fact that the specification for Jet A and Jet A–1 fuel is identified in the FAA approval certificate, no other type of fuel can be utilized at this time in the United States. Much work needs to be done before alternative fuels can safely be used in commercial aircraft operations with approval from the FAA."*

The importance of establishing alternative fuel specifications was recently highlighted in the *Technical Appendix to the National Plan for Aeronautics Research and Development and Related Infrastructure.* In this document, released in December 2008 by the Executive Office of the President's National Science and Technology Council, opportunities were listed where additional R&D focus may be warranted. One such opportunity relates to alternative fuels. Specifically, the document states:

> *"Certification in a timely manner could help enable alternative fuels for the civil aviation sector. An area of opportunity identified for potential increased emphasis is R&D efforts appropriate to promote the development of private sector capabilities to produce alternative fuel (including renewable fuels) in the large quantities necessary to conduct tests essential for the certification process. These tests include evaluation of fuel specification and fit for purpose properties, turbine hot section tests, combustor rig tests, and engine and auxiliary power unit endurance tests."*

A representative of the Commercial Aviation Alternative Fuels Initiative (CAAFI), a coalition drawn from all elements of the commercial aviation industry, fuel suppliers, universities, and U.S. Government agencies, recently highlighted the need for an ASTM specification for alternative fuels at a workshop held by the International Civil Aviation Organization. Dr. Lourdes Maurice, a witness at the hearing who also serves as one of FAA's representatives on CAAFI, will be able to provide further details on the challenges associated with the setting of alternative fuel specifications for aviation.

Recent Activities of Key Aviation-focused Alternative Fuels Stakeholders

There are a number of stakeholders whose views have helped shape the discussion of the technical, operational, and economic issues associated with the use of alternative fuels in aviation. Many of these stakeholders are involved in research initiatives associated with the use of alternative fuels in the aviation sector. They represent federal, industry, and global interests.

National Aeronautics and Space Administration

NASA's Fundamental Aeronautics Program has been conducting a range of research activities related to alternate aviation fuels. For example, NASA is:

- Conducting fundamental reaction studies on the Fischer-Tropsch process. Although the process is well-established, NASA believes that there is significant potential for process improvement that will increase process yield and reduce cost and reduce energy consumption during the Fischer-Tropsch process which should translate to a decrease in carbon dioxide emissions. As a result, NASA research is focusing on investigating Fischer-Tropsch reaction kinetics and developing a nanotechnology based catalyst. The process improvements resulting from NASA laboratory reactor studies will be implemented in the Air Force Research Laboratory's Fischer-Tropsch pilot plant. Scientists and researchers from NASA's Glenn Research Center are conducting this research in the Alternative Fuel Research Laboratory. Partners in this effort include the FAA, DOD, the Department of Energy (DOE), General Electric, Pratt and Whitney, Boeing and the University of Kentucky's Center for Applied Research.
- Generating a database of properties for the use of alternate fuels in aviation. The database of key properties such as thermal stability and freezing point is being generated to evaluate various alternate fuels for application to aviation uses and provides an independent assessment of these fuels.
- Modeling growth processes for biofuel feedstock. Under a non-reimbursable Space Act Agreement, NASA is partnering with Seambiotic, Inc. on a project aimed at biomass process cost reduction. The goal of the Space Act Agreement is to make use of NASA's expertise in large scale computational modeling and combine it with Seambiotic's biological process modeling to make significant advances.
- Performing engine and flight testing with alternate fuels in collaboration with Pratt & Whitney, the Air Force Research Laboratory, Aerodyne Research, FAA, and the Environmental Protection Agency (EPA). For example, NASA's DC–8 at the Dryden Flight Research Center was recently used to evaluate aircraft performance and emissions using alternate fuels. Fuels used for the ground tests were 100 percent synthetic fuels and 50/50 blends of synthetics and regular jet fuel. NASA believes that synthetic fuels may have fewer particulates and other harmful emissions than standard jet fuel and is attempting to validate that hypothesis. The tests used sampling probes placed downstream from the DC–8's right inboard engine. Researchers are examining the plume chemistry and particle evolution to compare it to that of standard jet fuel.

Federal Aviation Administration

In addition to its involvement in the Commercial Aviation Alternative Fuels Initiative described later in this section, FAA may have some legislative direction related to alternative fuels in pending legislation. The agency was directed in the House-passed *FAA Reauthorization Act of 2007* [H.R. 2881, Sec. 914] to *"establish a research program related to developing jet fuel from alternative sources (such as coal, natural gas, biomass, ethanol, butanol, and hydrogen) through grants or other measures authorized under section 106(l)(6) of such title, including reimbursable agreements with other federal agencies."* The bill further directed that in conducting the program, the Secretary *"provide for participation by educational and research institutions that have existing facilities and experience in the development and deployment of technology for alternative jet fuels."*

The bill also directed, within the section describing the Continuous Lower Energy, Emissions, and Noise (CLEEN) program [Sec. 505] that the FAA Administrator, in coordination with the NASA Administrator, *"enter into a cooperative agreement, using a competitive process, with an institution, entity, or consortium to carry out a program for the development, maturing, and certification of CLEEN engine and airframe technology for aircraft over the next 10 years."* Performance objectives for the program, to be achieved by September 30, 2015 included the *"determination of the feasibility of the use of alternative fuels in aircraft systems, including successful demonstration and quantification of the benefits of such fuels."*

Legislation [H.R. 915] to authorize appropriations for FAA for fiscal years 2009 through 2012 was recently marked up by the House Committee on Transportation and Infrastructure. The direction to FAA on alternative fuels and CLEEN program is maintained [Sections 505 and 913] in that bill.

Department of Defense

Knowledge gained from research on alternative fuels being conducted by DOD, the Air Force and the Defense Advanced Research Projects Agency (DARPA) in particular, is beneficial to the aviation community since test results can be extended to commercial aircraft.

The Air Force has been investigating synthetic fuels produced using the Fischer-Tropsch process, even though it recognizes that synthetic fuels will not lead to fewer emissions of carbon dioxide, the greenhouse gas primarily responsible for global climate change. According to a recent article in *Flight International,* the Air Force *"is uninterested in fuels made from feedstocks that compete with food supply or require huge amounts of land for production."* In that same article, the Air Force's Alternative Fuels Certification Office director was reported as having said that the service is planning to apply lessons learned from its Fischer-Tropsch initiative to an expanded alternative fuel development program that includes biofuels. The Air Force's involvement in alternative fuels is understandable: It has been reported that the service uses more aviation fuel than all other branches of the U.S. military combined. In 2007, this amounted to 2.5 billion gallons—about 10 percent of the total used by the entire U.S. domestic aviation-fuel market. The Air Force has set a goal of running half of its domestic operations on a 50/50 blend of synthetic and conventional jet fuel by 2016.

DARPA has also shown a growing interest in biofuels. *Biodiesel Magazine* has reported that DARPA's BioFuels program recently awarded two research contracts aimed at developing a scalable process for the cost-effective and large-scale production of algae oil to be processed into an alternative to JP–8 jet fuel. In one contract valued at $43 million, General Atomics will lead a team of 18 university and industrial partners in a three-year project. The contract will conclude with a pre-pilot-scale demonstration. In the second contract, Science Applications International Corp. (SAIC), along with industrial and academic organizations from Georgia, Florida, Hawaii and Texas will investigate all phases of an algae development program. It has been reported that during the first 18 months of the project, the two teams will try to get costs of algae-based oil down to $2 a gallon. It was also reported that, in the following 18 months, they will attempt to drop it to $1 a gallon and build a 30- to 50-acre demonstration facility.

Commercial Aviation Alternative Fuels Initiative

The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a coalition drawn from all elements of the commercial aviation industry, fuel suppliers, universities, and U.S. Government agencies, including FAA, DOE, NASA, the Air Transport Association of America (ATA), the Aerospace Industries Association (AIA), and the Airports Council International-North America (ACI–NA). CAAFI staff come from its members. For example, Dr. Lourdes Maurice, a witness at this hearing, is from FAA and serves as CAAFI's Environmental Lead. The coalition's stated goal is to enhance energy security and environmental sustainability for aviation by exploring the potential use of alternative fuels. CAAFI provides a forum for the U.S. commercial aviation community to engage the emerging alternative fuels industry and to work together, share and collect needed data, and motivate and direct research on aviation alternative fuels.

CAAFI participants meet annually to give updates on the state of alternative fuel developments, identify gaps and hurdles, and decide on next steps required in the research, development and deployment process. Work to date has included the creation of roadmaps to communicate aviation needs and solutions; disseminating flight-test information on synthetic fuels and biofuels; supporting R&D on low carbon fuels sourced from plant oils, algae and biomass; understanding life cycle environmental impacts of production and use of alternative fuels; and planning for certification in 2009 of a 50 percent synthetic fuel, 2010 for 100 percent synthetic fuel, and 2013 for biofuels. CAAFI's Executive Director told Subcommittee staff that the coalition is presently executing a major update to its roadmaps as a result of the Dayton workshop discussed below and projected that they would be available in the near future.

Two CAAFI initiatives relevant to the focus of this hearing are worth noting:

- At CAAFI's request, the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER), a university, industry, and government collaborative that researches solutions for existing and anticipated aviation-related noise and emissions problems, is conducting a study on alternative fuels for commercial aviation. The study, conducted by MIT and the RAND Corporation, compares a set of potential alternative jet fuels on the basis of compatibility with existing aircraft and infrastructure, near-term production potential, near-term production costs, life cycle greenhouse gas emissions, emissions impacting air quality, and relative merit of using the fuel in aviation versus ground transportation. The focus is on alternative jet fuels that could be commercially available in the next decade using North American resources. According to CAAFI, the report documenting PARTNER's research is under internal review and is scheduled to be released in May of this year. PARTNER is an FAA/NASA/Transport Canada-sponsored Center of Excellence.
- Last January, CAAFI held a Research & Development Team workshop in Dayton, OH. The workshop's goals were to update ongoing R&D activities and needs; develop an overall R&D roadmap and a renewable fuel feedstock roadmap; and align aviation efforts with broader government and private sector energy initiatives. The workshop was an opportunity for makers of biofuel feedstocks to meet with funding sources. Federal attendees included representatives of the Air Force; Departments of Agriculture and Energy; the National Science Foundation; EPA; FAA; and NASA. In commenting on the progress that the alternative fuels effort had made in a short time, Boeing's representative and R&D team co-lead said:

  > *"We've made great strides in making aviation a central focus of alternative fuels research including four successful flight programs [These flight programs are described later in this section]. Our efforts today will help focus industry and government—suppliers and users on how to move forward to deployment on those fuels that have been tested and how to mature additional technologies."*

  One of the participants at the workshop introduced a new Fuel Readiness Level (FRL) scale to allow a common understanding of fuel development steps from R&D to fuel certification to business development. The new scale incorporates civilian and military Technology Readiness Level (TRL) scales and was advanced as a useful tool and common language for tracking the fuel development, approval and commercialization process.

Departments of Energy and Agriculture

The U.S. Departments of Energy (DOE) and Agriculture (USDA) announced in January 2009 that they were providing up to $25 million in funding for research and development of technologies and processes to produce biofuels, bioenergy, and high-value biobased products. USDA and DOE issued a joint funding opportunity announcement (FOA) for several types of projects aimed at increasing the availability of alternative renewable fuels and biobased products. The projects, DOE and USDA said, will aim to create a diverse group of economically and environmentally sustainable sources of renewable biomass.

In commenting on the announcement, the Air Transport Association said that it was the first step in implementing provisions found in the 2008 Farm Bill that provide grants for commercial-scale biofuel demonstration projects, including those that could ultimately produce clean, homegrown, renewable jet fuel.

ATA's President and CEO added: *"This commitment to the research and development of advanced renewable fuels will allow for commercial-scale demonstration projects and other important activities that will move us closer to commercially viable, environmentally friendly alternative jet fuel. ATA and its member airlines look forward to working with the Federal Government to further promote the rapid development of these exciting new fuel sources."*

European Commission

In February 2009, the Office National d'Etudes et de Recherches Aerospatiales (ONERA) was chosen by the European Commission's Directorate-General for Energy and Transport as prime contractor to conduct a strategic feasibility and impact study on alternative fuels for aviation called Sustainable Way for Alternative Fuel and Energy in Aviation (SWAFEA). ONERA is leading a consortium of 19 industry and research partners representing aircraft manufacturing, air transport, oil industry, research and consulting sectors. ONERA is the French national aerospace research center and was originally created by the French government in 1946.

By providing a clearer view of the feasibility of different alternative fuel options, the SWAFEA study will also help determine research paths to prepare future European programs as well as providing a foundation for potential international partnerships extending beyond Europe, including the United States.

According to the ONERA press release announcing the program, the SWAFEA study will be carried out over a 26-month period, *"synthesizing our current knowledge of the different alternatives to conventional jet fuel, and issuing recommendations and a road map for their deployment in the medium-term."* Furthermore, the press release stated that the study *"will call on a multi-disciplinary approach to integrate all issues involved, spanning technical, organizational, economic, society, environmental and geopolitical aspects. This inventory of the "state of the art" will be backed by experimentation."*

International Air Transport Association

The International Air Transport Association (IATA), representing 230 airlines that account for 93 percent of scheduled international air traffic, released a report in December 2008 entitled *"IATA 2008 Report on Alternative Fuels."*

The report's findings were listed as:

- *"The potential for biomass as feedstock supply is high, even though the differences in sources and locations require multiple technologies for conversion.*
- *The oil price will stay low as long as deep recession causes more demand destruction. However, projects to develop new reserves are being stopped. Once recession ends supply-demand pressures are widely expected to take oil prices back up to the $100 a barrel level.*
- *"Peak oil" is not reached yet; the current oil reserves are high enough to supply the world for the next 42 years of oil, calculated with current consumption.*
- *The impact of the European Union emissions trading scheme is estimated to add around five percent to jet kerosene fuel costs for flights in and out of the EU from 2012.*
- *The current certification process of aviation fuels can take up to four phases in testing: testing on specification properties, fit-for-purpose properties, component testing and engine testing. When all the testing steps have to be performed the amount of fuel is about 1000 m3 (250.000 gallon).*
- *Some of the technologies, both in biochemical as thermo chemical conversion, are well established and have produced renewable jet fuel for testing."*

The report's recommendations were stated as:

- *"Applying biomass as a feedstock requires further analysis in sustainability criteria in order to ensure that negative nature changes from historic actions, like deforestation, are not repeated.*
- *The uncertainty in calculated greenhouse gas emissions needs to be reduced. This can be done by increasing the quality of models and performing measurements at production plants.*
- *Most of the technologies that are able to produce jet fuel from the currently available feedstock need more research and development to become commercial.*
- *The technologies that are in the end of the innovation phase require actions that reduce the risk of commercialization.*
- *Industry stakeholders are taking various diversified actions to promote sustainable alternative fuels for aviation. It is recommended to the industry to collaborate in directly non-competitive issues to reduce the accessibility hurdles of innovators."*

International Civil Aviation Organization

The search for alternative fuels for aviation is not limited to the U.S. The International Civil Aviation Organization (ICAO), an agency of the United Nations, held a workshop in Montreal, Canada on Aviation and Alternative Fuels in February 2009 The main goals of the workshop were identified by ICAO as stimulating a dynamic exchange of views and initiating work on a global roadmap for the effective, and the responsible contribution of aviation alternative fuels to protecting the environment. The event, ICAO noted, was designed as a preparatory event to a world conference in November 2009 that will showcase progress and establish a road map for the implementation of alternative fuels for aviation.

In his opening remarks, ICAO's Secretary General said:

> *"Alternative fuels on their own are not, and never will be, the solution. They should, however, be part of a comprehensive energy strategy. There are very few low-carbon energy options for reducing aviation emissions, and alternative fuels may be the only option for large scale use in the short-term. Nevertheless, the decision to develop and use alternative fuels must be an informed and responsible one, taking into account total life cycle costs and carbon footprints."*

In summarizing the workshop in his closing remarks, ICAO's Director of the Air Transport Bureau said:

> *"As we heard over the last three days, much progress has been achieved to date and there are high expectations for the use of more environmentally friendly drop-in alternative fuels for aviation in the short-term. At the same time, research is underway with potential for a globally-available alternative fuel in the mid to long-term. However, concerted international action will be necessary to translate this possibility into a reality."*
>
> *"It is clear from this workshop that aviation alternative fuels could be a win-win solution in that they will reduce aviation's dependence on climate changing fossil fuels while stabilizing the economic volatility associated with conventional fossil fuels. Now, let us take another look at these alternatives.*
>
> *While synthetic fuels are already or soon to be available, their environmental benefit over conventional fuels is unclear. They do however address the issue of energy security and also diversify energy sources. Biofuels, on the other hand, seem to offer environmental benefits but the production scalability issues need to be resolved. Regardless of these challenges, the importance of alternative fuels in the development of balanced and robust strategies to mitigate the impact of aviation on the environment is unquestionable."*
>
> - *"As is so often the case in recent industrial undertakings where the supplier and consumer base is not limited to any one country or region, global cooperation will be essential in ensuring the consistent and standardized use of alternative fuels. This is especially true of aviation which relies on a standard and consistent infrastructure across the world for its efficient operation. However, at present, the international aviation community has not achieved an integrated approach to alternative fuels. While regional and national efforts by airlines, manufacturers, and fuel producers have done an excellent job of bringing together the expertise to consider technical issues, the subject has been addressed in a fragmented way. ICAO can help with better coordination since it is the only globally recognized forum to deal with aviation."*

Partnerships between Major Carriers and Airframe/Engine Vendors and Fuel Providers

Several partnerships have conducted flight demonstrations using biofuels in the past year:

- In February 2008, a Virgin Atlantic Boeing 747–400 flew from London's Heathrow Airport to Amsterdam's Schiphol Airport partially fueled by a 20 percent mix of biofuel derived from coconut and babassu oil with conventional jet fuel. Other test participants were Boeing, General Electric and Imperium Renewables. Mr. Bill Glover, a witness at the hearing representing the Boeing Commercial Airplane Company, will provide further details about this and other demonstrations involving Boeing aircraft.
- In May 2008, Jet Blue teamed with Airbus, International Aero Engines (IAE) and Honeywell Aerospace to pursue the development of sustainable biofuels derived from algae and other non-food vegetable oils for use in commercial aircraft. In addition to investigating the environmental benefits of biofuels, the partnership plans to conduct research into whether biofuels could poten-

tially be developed that would expand payload-range aircraft performance, reduce fuel burn, and increase engine reliability and durability.

- In July 2008, Rolls-Royce and British Airways announced that they were starting a test program to research alternative fuels for the aviation industry. The companies invited suppliers to offer alternative fuel samples for testing on an engine taken from a British Airways Boeing 747. The tests will be carried out on an indoor engine testbed. After a selection of up to four alternative fuels, these fuels will undergo laboratory testing before being delivered to Rolls-Royce for further testing. It was recently reported that the partnership encountered difficulty in securing alternative fuel samples in the desired quantities.
- In December 2008, an Air New Zealand Boeing 747–400 powered by Rolls-Royce RB211 engines flew a two-hour demonstration flight using a 50–50 jatropha and conventional jet fuel mix. The jatropha-derived fuel was supplied by Terasol Energy, which is based in India. Other test participants were Boeing, Rolls-Royce, and Honeywell subsidiary UOP.
- In January 2009, a Continental Boeing 737–800 powered by two CFM56–7B engines made a two-hour demonstration flight at Bush International Airport in Houston using a biofuel mixture of jatropha and algae that was provided by Honeywell UOP. The test included powering the right engine with the biofuel mix, turning it off and on as well as rapidly accelerating and slowing down the plane. A borescope inspection was done on the engine using the biofuel mixture; no change in engine condition was found. This followed a November 2008 ground test of the biofuel mixture at which time fuel consumption at different power settings was measured. Among Continental's reasons for conducting a flight demonstration were helping collect needed data to support fuel qualification/certification for use by the aviation industry; showing the public that biofuel is safe and that it works; and stimulating research and development on biofuel use in aviation. Other test participants were Boeing and the engine's manufacturer, CFM. Mr. Shannon Holden, a witness at the hearing representing Continental Airlines, will provide further details on Continental's test and interest in biofuels.
- In January 2009, a Japan Air Lines Boeing 747–300 outfitted with Pratt & Whitney JT9D engines made a one hour flight at Tokyo's Haneda Airport using a mixture of camelina, jatropha, and algae. Camelina was sourced from Sustainable Oils, a U.S. based provider. Terasol provided the jatropha oil. Other test participants were Boeing, Pratt & Whitney, and Honeywell UOP. Dr. Alan Epstein, a witness at the hearing representing Pratt & Whitney, will provide further details on the test.

Sustainable Aviation Fuel Users Group

Formed in September 2008, the Sustainable Aviation Fuel Users Group brings together major airlines, Boeing, and biofuel provider Honeywell UOP with the goal of accelerating the development and commercialization of sustainable new aviation fuels. The group's charter is to enable the commercial use of renewable fuel sources that can reduce greenhouse gas emissions, while lessening commercial aviation's exposure to oil price volatility and dependence on fossil fuels. The group receives support and advice from two environmental organizations, the World Wildlife Fund and the Natural Resources Defense Council (NRDC). Airline members are Air France, Air New Zealand, All Nippon Airways, Cargolux, Gulf Air, Japan Airlines, KLM, Scandinavian Airlines System (SAS), and Virgin Atlantic. Collectively, these carriers account for over 15 percent of annual commercial use of jet fuel.

According to Honeywell UOP, the group has announced two initial sustainability research projects. An Assistant Professor at Yale University's School of Forestry & Environmental Studies, through funding provided by Boeing, will conduct the first peer-reviewed, comprehensive sustainability assessment of jatropha curcas, to include life cycle CO_2 emissions and the socioeconomic impacts to farmers in developing nations. Similarly, NRDC will conduct an assessment of algae to ensure it meets the group's sustainability criteria.

Algal Biomass Organization

The Algal Biomass Organization (ABO) is a trade association dedicated to the advancement of the algal biomass industry. Formed in May 2008 out of the 2007 Algae Biomass Summit, ABO's goal is to promote the development of viable commercial markets for renewable and sustainable commodities derived from algae. The organization is composed of companies, some aviation-related such as Boeing, air carriers such as Continental, Air New Zealand, Virgin Atlantic, and FedEx; along with researchers, entrepreneurs, harvesters, processors and end-users of algae. Among the primary purposes of the organization, ABO cites:

- Facilitating commercialization and market development of microalgae biomass specifically for biofuels production and greenhouse gas abatement.
- Establishing cutting edge research and commercialization summits and other meeting opportunities.
- Developing quality and measurement best practices for algal biomass, products, systems technology, and econometrics.

Chairwoman GIFFORDS. Good morning everyone. This hearing will now come to order.

Good morning, it is a pleasure to welcome all of you to today's Subcommittee hearing. We have an impressive panel of experts appearing before us this morning, and I look forward to a good discussion.

Let me come right to the point. I think that today's hearing is one of the most important that this subcommittee is going to have all year. And why do I say that? It is no secret that this nation is wrestling with twin challenges of achieving energy independence and protecting and preserving our environment. These are very difficult challenges, but they are challenges we have to address and they are challenges that we have to meet.

Every sector of our economy is going to have to play its part in helping to reduce our dependence on foreign energy as well as combating climate change.

We all know the importance of aviation to our economy and to our quality of life, but that doesn't give us a free pass. We only have to look at the recent European moves on aviation emissions penalties to realize what is going on.

This Congress will be focused on finding the best path forward as it considers climate and energy legislation in the coming months.

This hearing will be the first opportunity for our committee to examine one important option for addressing both of those challenges, namely the potential offered by aviation biofuels.

In that regard, we have seen increased attention in recent months to the role that biofuels could play as a future aviation fuel source. There even have been recent flight demonstrations of biofueled aircraft, and we will hear about some of those flight tests at today's hearing.

Yet, the limited experience to date with the latest generation of aviation biofuels doesn't provide enough information to know what role they will ultimately play in aviation, and that is not surprising. As a Nobel prize-winning physicist once said, prediction is very difficult, especially if it involves the future.

Now, we also don't yet have enough information on the potential unintended consequences of different types of aviation biofuels, and in particular, their impacts on land use and water use if they would go into widespread production.

I called today's hearing so that the Subcommittee can start to get some real answers on the outstanding questions that will have to be addressed if biofuels are to play a significant role in aviation in the future. Most importantly, I would like to find out what is being done by both the Federal Government and the private sector to address these challenges.

We have first-rate R&D capabilities at NASA, the FAA, DOD, and DOE, as well as America's companies, research institutes, and universities. However, those capabilities will not suffice without clear R&D roadmaps, program plans, and resource commitments to guide our efforts.

I am afraid the odds of success will be reduced without an integrated federal/private sector approach to evaluating the potential benefits and costs of aviation biofuels, including a systematic plan to understand their impacts on both existing and future aircraft technologies. We have to quote Yogi Berra. I love a committee with good quotes: "You've got to be very careful if you don't know where you're going, because you might not end up getting there."

So we need to get there as a nation, and I look forward to hearing from today's panelists about that productive path forward. And again, I want to welcome all of you to this very important hearing.

And now I will yield to Mr. Olson for any opening remarks he would like to make.

[The prepared statement of Chairwoman Giffords follows:]

PREPARED STATEMENT OF CHAIRWOMAN GABRIELLE GIFFORDS

Good morning, it's a pleasure to welcome you to today's Subcommittee hearing.

We have an impressive panel of experts appearing before us this morning, and I look forward to a good discussion.

Let me come right to the point.

I think that today's hearing is one of the most important that this subcommittee will hold this year.

Why do I say that?

It's no secret that this nation is wrestling with the twin challenges of achieving energy independence and preserving our environment.

They are tough challenges, but we've got to succeed.

Every sector of our economy is going to have to play its part in helping to reduce our dependence on foreign energy as well as helping to combat global warming.

We all know the importance of aviation to our economy and to our quality of life, but that doesn't give it a "free pass."

We only have to look at the recent European moves on aviation emissions penalties to realize that.

This Congress will be focused on finding the best path forward as it considers climate and energy legislation in the coming months.

This hearing will be the first opportunity for our committee to examine one important option for addressing both of those challenges—namely the potential offered by aviation biofuels.

In that regard, we have seen increased attention in recent months to the role that biofuels could play as a future aviation fuel source.

There even have been recent flight demonstrations of biofueled aircraft, and we will hear about some of those flight tests at today's hearing.

Yet, the limited experience to date with the latest generation of aviation biofuels doesn't provide enough information to know what role they will ultimately play in aviation.

That's not surprising. As the Nobel prize-winning physicist Niels Bohr once said: *"Prediction is very difficult, especially about the future."*

We also don't yet have enough information on the potential *"unintended consequences"* of different types of aviation biofuels, and in particular, their impacts on land use and water use if they would go into widespread production.

I called today's hearing so that the Subcommittee can start to get some answers on the outstanding questions that will have to be addressed if biofuels are to play a significant role in aviation in the future.

Most importantly, I would like to find out what is being done by both the Federal Government and the private sector to address those challenges.

We have first-rate R&D capabilities at NASA, the FAA, DOD, and DOE, as well as in America's companies, research institutes, and universities.

However, those capabilities will not suffice without clear R&D roadmaps, program plans, and resource commitments to guide our efforts.

I'm afraid the odds of success will be reduced without an integrated federal/private sector approach to evaluating the potential benefits and costs of aviation biofuels, including a systematic plan to understand their impacts on both existing and *future* aircraft technologies.

Or to quote another notable person, Yogi Berra: *"You've got to be very careful if you don't know where you're going, because you might not get there."*

I think we need to *"get there"* as a nation, and I look forward to today's hearing as an important step towards crafting a productive path forward.

With that, I again want to welcome our witnesses, and I now will yield to Mr. Olson for any opening remarks he would care to make.

Mr. OLSON. Thank you, Madam Chairwoman, and thank you for calling this morning's hearing. My thanks, too, to our witnesses for taking the time out of your busy schedules to appear before us today. I know that you invested many hours in preparation for today's hearing, and I am grateful for all of your efforts.

While aviation is a relatively small contributor of greenhouse gas emissions, the marketplace compels the industry to continue to invest in technologies that make the system and the aircraft that operate within it more efficient and more environmentally benign, no matter the vast performance improvements that have been achieved over the past couple of decades.

Fuel price spikes that occurred during 2008 were a stark signal that if we are to obtain a robust and affordable aviation system, we must take aggressive steps to develop alternative sources of fuel.

World demand for petroleum resources and production caps imposed by OPEC are again driving fuel prices to higher levels, and in doing so, they threaten our economy and our quality of life.

Biofuels present a possible new source of energy that could power our aircraft and at the same time greatly diminish the amount of carbon emitted into the atmosphere. I am optimistic that through cooperative government and industry research and development, the marketplace will be able to develop fuels that will meet these challenges.

I commend the work done at NASA, the FAA, and by the private companies, some of whom are represented here today. I am hopeful that the good work being done is both widely communicated and adequately funded. In my mind, this is the kind of research our Federal Government should be funding, the kind which has practical use for private industry that will eventually benefit consumers and in doing so help to end our dependence on foreign sources of energy.

I look forward to hearing your testimony and to our discussion, and please don't think I am going to be easy on Mr. Shannon just because after only two months as a Member of Congress, I have already achieved elite Status on Continental Airlines.

Thank you very much for being here today. Madam Chairwoman, I yield back.

[The prepared statement of Mr. Olson follows:]

PREPARED STATEMENT OF REPRESENTATIVE PETE OLSON

Madame Chairwoman, thank you for calling this morning's hearing, and my thanks too, to our witnesses for taking time out of their busy schedules to appear before us today. I know that you have invested many hours in preparation for today's hearing, and I am grateful for all of your efforts.

While aviation is a very small contributor of greenhouse gas emissions, the marketplace compels industry to continue to invest in technologies that make the system—and the aircraft that operate within it—more efficient and more environmentally benign, no matter the vast performance improvements that have been achieved over the past couple of decades.

Fuel price spikes that occurred during 2008 were a stark signal that, if we are to retain a robust and affordable aviation system, we must take aggressive steps to develop alternative sources of fuels. World demand for petroleum resources, and production caps imposed by OPEC, are again driving fuel prices to ever higher levels, and in so doing, they threaten our economy and our quality of life.

Biofuels present a possible new source of energy that could power our aircraft, and at the same time, greatly diminish the amount of carbon emitted into the atmosphere. I am optimistic that through cooperative government and industry research and development, the marketplace will be able to develop fuels that will meet these challenges.

I commend the work done at NASA, the FAA, and by the private companies, some of whom are represented here today, and am hopeful that the good work being done is both widely communicated and adequately funded.

In my mind, this kind of research our Federal Government should be funding, the kind which has practical use for private industry that will eventually benefit consumers, and in doing so helping to preserve our environment and our freeing us on our reliance on foreign sources of energy.

I look forward to hearing your testimony and to our discussion, and please do not think that I will be easy on Mr. Shannon just because after only two months as a Member of Congress I've already achieved Elite Status on Continental Airlines.

Madame Chairwoman, thank you again.

Chairwoman GIFFORDS. Thank you, Mr. Olson. If there are Members who wish to submit additional opening statements, their statements will be added to the record at this point.

At this time I would like to introduce our witnesses. First up we have Dr. Jaiwon Shin who is the Associate Administrator for the Aeronautics Research Mission Directorate, NASA. Welcome. Dr. Lourdes Maurice who is the Chief Scientific and Technical Advisor for Environment in the FAA's Office of Environment and Energy and is the Environmental Lead on the Commercial Aviation Alternative Fuels Initiatives, or CAAFI. Good morning. Dr. Alan Epstein who is Vice President of Technology and Environment at Pratt & Whitney. Good morning. We have also Mr. Billy Glover who is the Managing Director of Environment Strategy at Boeing. And finally, we have Mr. Holden Shannon who is the Senior Vice President of Global Real Estate and Security at Continental Airlines. Welcome.

As our witnesses should know, we will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and when you have completed your spoken testimony, we will begin with questions. Each Member will have five minutes to question the panel, and why don't we start with Dr. Shin.

STATEMENT OF DR. JAIWON SHIN, ASSOCIATE ADMINISTRATOR, AERONAUTICS RESEARCH MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Dr. SHIN. Good morning, and thank you, Chairwoman Giffords, Ranking Member Olson, and Members of the Subcommittee. Thank you for the opportunity to appear before you today to provide NASA's perspective on the emerging use of biofuels for aviation, including the agency's current research in this area.

Growth in the air transportation system is vital to the economic well-being of our nation. In order to meet the projected growth in aviation, significant challenges must be overcome including environmental sustainability. NASA is conducting cutting-edge research to dramatically improve aircraft efficiency and revolutionize aircraft operations in the national airspace system, both of which will reduce the environmental impact of aviation. Biofuels offer the potential for the significantly reduced carbon footprint over the entire life cycle, from fuel production to utilization. Current NASA research on increasing aircraft efficiency and operational procedures, coupled with the use of biofuels, presents a possibility of dramatically reduce the carbon footprint for the aviation sector despite the projected growth.

Recognizing the importance of biofuels for the future of aviation, NASA has initiated a modest research effort in 2007 that builds upon the existing expertise in fuel chemistry and processing, combustion, and gas turbine engines to address some of the challenges associated with the application of these fuels for aviation. However, NASA also recognizes that the widespread use of biofuels for aviation will require a concerted effort by multiple government agencies, aerospace industries, academia, and biofuel producers. The need for a coordinated approach to enabling new fuel sources is highlighted as one of the goals of the National Plan for Aeronautics Research and Development and Related Infrastructure.

While recent successful flight tests has shown the feasibility of using blends of jet fuel and different types of biofuels under controlled conditions, several technical and economic barriers remain for widespread use of biofuels in the aviation sector.

The major question related to the production of biofuels is whether they can be made sustainably, economically and at a scale sufficient to support the aviation industry. Additional basic and applied research will be required to scale up the process for producing large quantities of biomass that are economically viable and sustainable.

There are uncertainties related to the application of biofuels for aviation because of the extremely limited amount of testing conducted to date with these fuels. Most of the NASA research is focused on issues related to the application of alternative fuels.

We need to study the combustion process using alternative fuels and understand whether the combustor performance is different from that achieved when jet fuel is used.

The impact of the use of alternative fuels on aircraft safety is another area that needs further study. Foundational research on the effect of alternative fuels on engine performance and degradation of engine materials is required to identify potential safety issues and develop mitigation strategies.

NASA is conducting long-term foundational research to understand the effects of various alternative fuels on aircraft engine emissions. Research includes laboratory combustion testing under controlled conditions and ground engine testing under simulated flight conditions.

All of NASA's research efforts on alternative fuels to date have been focused on the application of synthetic jet fuel produced from natural gas and gasification of coal and conversion of the gases to liquid fuel by the Fisher-Tropsch, or F–T, process. Current research using F–T fuel is providing valuable insight into emission characteristics of alternative fuels. We are also studying ignition times, flame speeds, and chemical kinetics. These are parameters which affect the design of new combustors.

As the second generation of biofuels becomes available, there is a need for research to understand these parameters for biofuels so that we can effectively design new low-emission combustors that are fuel-flexible.

The effects of biofuels and engine emissions will also be determined through a combustion laboratory testing and ground engine testing under simulated flight conditions.

In conclusion, NASA participates in alternative fuel related road-mapping and planning activities that are under way, most prominently led by CAAFI. We also participate in Air Force led efforts to develop rules and tools for use in predicting the life cycle greenhouse gas emissions of alternative fuels, and we are on the Advisory Board of FAA's PARTNER Center of Excellence which conducts alternative fuel emissions and life cycle studies. We are willing to participate in this alignment of alternative fuels activities along with other government agencies, industries, and academia as appropriate. These roadmaps are identifying the research, development, and demonstration needs, and defining the roles and responsibilities for multiple organizations.

NASA believes its expertise and research capabilities in combustion, turbine engine performance, fuel processing, materials, and computational modeling can be utilized as part of a nationally coordinated research effort to address some of the key challenges that must be overcome for widespread use of second-generation biofuels in future aviation.

I would be happy to respond to any questions you or the other Members of the Committee may have. Thank you.

[The prepared statement of Dr. Shin follows:]

PREPARED STATEMENT OF JAIWON SHIN

Chairwoman Giffords, Ranking Member Olson, and Members of the Subcommittee, thank you for the opportunity to appear before you today to provide a NASA perspective on the emerging use of biofuels for aviation, including the Agency's current research in this area.

Growth in the air transportation system is vital to the economic wellbeing of our nation. In order to meet the projected growth in aviation, significant challenges must be overcome including environmental sustainability. NASA is conducting cutting-edge research to dramatically improve aircraft efficiency and revolutionize aircraft operations in the national airspace system, both of which will reduce the environmental impact of aviation. An emerging technology area that has attracted considerable attention recently is the use of renewable energy sources such as aviation biofuels. Biofuels offer the potential for a significantly reduced carbon footprint over the entire life cycle, from fuel production to utilization. Current NASA research on increasing aircraft efficiency and operational procedures, coupled with the use of biofuels, presents a possibility to dramatically reduce the carbon footprint for the aviation sector despite the projected growth.

The first generation of biofuels, such as those produced from soybean and corn, is derived from food products and requires large land masses. Second generation biofuels from energy crops such as switchgrass and woody feedstocks have higher productivity and smaller land use. The second and third generation of biofuels, produced from jatropha, camelina, algae, and halophytes, appears to impact much smaller land masses and is not derived from food products, which is the reason for strong world-wide interest for this class of materials.

NASA recognizes the importance of biofuels for the future of aviation and in 2007 initiated a modest research effort that builds upon the existing expertise in fuel chemistry and processing, combustion, and gas turbine engines to address some of the challenges associated with the application of these fuels for aviation. However, NASA also recognizes that the widespread use of biofuels for aviation will require a concerted effort by multiple government agencies, aerospace industries, academia, and biofuel producers. The need for a coordinated approach to enabling new fuel sources is highlighted as one of the goals of the National Plan for Aeronautics Research and Development and Related Infrastructure. As noted in the plan, the Commercial Alternative Aviation Fuels Initiative (CAAFI) is coordinating development and commercialization of "drop-in" alternative aviation fuels and is considering the feasibility, production, and environmental footprint—"well to wake"—of these fuels.

Challenges

While recent successful flight tests, including the Air New Zealand flight demonstration in December 2008, the Continental airlines flight in January 2009, and the JAL flight in January 2009, have shown the feasibility of using blends of jet fuel and different types of biofuels under controlled conditions, several technical and economic barriers remain for widespread use of biofuels in the aviation sector. The challenges can be grouped into two categories: biofuel production and application of biofuels. Most of the NASA research in this domain focuses on issues related to the application of biofuels.

The major question related to the production of biofuels is whether they can be made sustainably, economically and at a scale sufficient to support the aviation industry. It is NASA's opinion that additional basic and applied research will be required to scale up the process for producing large quantities of biomass that are economically viable and sustainable. This will require understanding the factors affecting the growth of biomass and translating that understanding to increase process yield. In addition, production processes that reduce energy use during the biomass to biofuel conversion process must be developed towards the goal of carbon neutrality, which can be achieved for the entire life cycle encompassing production and utilization of biofuels.

There are uncertainties related to the application of biofuels for aviation because of the extremely limited amount of testing conducted to date with these fuels. For alternative fuels not produced by the Fisher-Tropsch (F–T) process, the knowledge base of the characteristics and qualities of these fuels is incomplete, and many of the challenges may not be known yet. In order to understand these challenges, foundational research is required in many areas. We need to study the combustion process using alternative fuels and understand whether the combustor performance is different from that achieved when jet fuel is used. Of particular concern is the long-term performance of combustors and turbine engines burning alternative fuels. Because nitrogen oxide (NO_X) causes gourd-level smog and contributes to acid rain, the compatibility of alternative fuels with advanced, ultra-low NO_X combustor designs must be addressed as well.

Research will be needed to understand both gaseous and particulate matter emission characteristics from engines so that alternative fuels can be optimized for reducing emissions.

The other unknown is the effect of alternative fuels on the long-term durability of engine components, including advanced fuels from coal and natural gas.

The impact of the use of alternative fuels on aircraft safety is another area that needs further study. Flight tests with a blend of jet fuel and biofuels to date have been conducted under controlled conditions and have not yet indicated any major safety issues. However, one potential safety issue is leaks and degradation of seals in the aircraft fuel system because of the lower aromatic content of alternative fuels compared to that of jet fuel, which affects the expansion coefficient of seals. Any potential, unexpected degradation of engine components when alternative fuels are used could pose safety issues. Foundational research on the effect of alternative fuels on engine performance (including control system) and degradation of engine materials is required to identify potential safety issues and develop mitigation strategies.

Current NASA Research

NASA is conducting long-term foundational research to understand the effects of various alternative fuels on aircraft engine emissions. NASA intends to disseminate the results of its research to the greatest extent possible, and enters into collaborative relationships with other organizations such that the results will benefit the wider community. Research includes laboratory combustion testing under controlled conditions and ground engine testing under simulated flight conditions. NASA has recently modified several laboratory-scale combustion facilities to study combustion performance and emission characteristics with different types of alternative fuels and blends of alternative fuel with Jet-A. Research conducted in these facilities will provide the much needed emission data for alternative fuels as well as improved understanding of factors affecting gaseous and particulate emissions with the use of alternative fuels. An important feature of NASA's research is to understand the effect of alternative fuels on both gaseous and particulate emissions for advanced combustor designs that are being developed to reduce NO_X for future generations of aircraft.

All of NASA's research efforts on alternative fuels to date have been focused on the application of synthetic jet fuel produced from natural gas and gasification of coal and conversion of the gases to liquid fuel by the F–T process. Current research using F–T fuel is providing valuable insight into emission characteristics of alternative fuels. We are also studying ignition times, flame speeds, and chemical kinetics. These are parameters which affect the design of new combustors. As the second generation of biofuels becomes available, there is a need for research to understand these parameters for biofuels as well so that we can effectively design new low-emission combustors that are fuel-flexible. The understanding, coupled with improved emission prediction models, will enable the design of advanced, ultra-low emission engines with the flexibility to operate with a mix of fuels that range from blends of jet fuel with biofuel to 100 percent biofuel. Several examples of the type of alternative fuels testing conducted by NASA are provided below.

NASA, in partnership with industry, is conducting engine tests with alternative fuel to understand the emission characteristics. In 2008, NASA partnered with Pratt and Whitney to study emissions from a geared turbofan engine that was run with a blend of jet fuel and F–T fuel. The tests indicated that there was no significant difference in gaseous emissions, while confirming the benefits of F–T fuel in reducing particulate emissions. Initial results from these tests were presented at the Fundamental Aeronautics Program Second Annual Meeting held in Atlanta on October 7–9, 2008, and NASA will hold a workshop later this year to widely disseminate the results. In another collaboration with Pratt and Whitney, the U.S. Air Force Research Laboratory, Aerodyne, United Technologies Research Center, and NASA studied emissions from a PW308 turbofan engine run with 100 percent F–T fuel and a blend of jet fuel and F–T fuel. This study provided detailed understanding of the nature of particulate emissions resulting from the combustion of F–T fuel under engine operating conditions.

Recently, in January 2009, NASA, in partnership with 11 other organizations that include the Federal Aviation Administration, U.S. Air Force Research Lab (AFRL), Environmental Protection Agency, Boeing, GE Aviation, and Pratt & Whitney, conducted ground tests using a NASA-owned DC–8 plane to study emissions from engines burning alternative fuel, which included two 100 percent F–T fuels and blends of jet fuel with the two F–T fuels. The test provided data that will improve understanding of the evolution of particulate emission and plume chemistry for engines burning alternative fuel.

In addition to extensive experience in testing and analysis, NASA has expertise in multi-scale modeling of fluid mechanical processes. This is being recognized by the private sector engaged in the development of large scale processes for growth of the second generation biofuel biomass source material (such as algae and halophytes). In order to meet the challenges of large-scale production of second generation biofuel biomass economically, the fluid mechanical processes which transport nutrients and waste in the bioreactor need to be understood and modeled. The models can then be employed to design improved bioreactors that can reduce the cost of biomass production. NASA is working with industrial partners to develop multi-scale, fluid-mechanics models that integrate physical and biological processes in a bioreactor. NASA has laboratory scale reactors suitable for validating multi-scale, fluid-mechanics models to be used for improved bioreactor designs.

Need for Collaboration

NASA believes that long-term, foundational research on understanding of fuel processing, combustor and engine performance, durability of engine components, and emission characteristics will be required for application of second generation biofuels in aviation.

Realization of the full potential for the application of alternative fuels in aviation requires a coordinated effort among multiple government agencies, aerospace companies, academia, and fuel producers. This is an area of significant national importance and will require a strong national effort.

NASA participates in alternative fuel related road-mapping and planning activities that are underway, most prominently led by the Commercial Aviation Alternative Fuels Initiative, or CAAFI. We also participate in Air Force led efforts to develop rules and tools for use in predicting the life cycle greenhouse gas emissions of alternative fuels and are on the Advisory Board of FAA's PARTNER Center of Excellence which conducts alternative fuel emissions and life cycle studies. We are willing to participate in this alignment of alternative fuels activities along with other government agencies, industries, and academia as appropriate.

These roadmaps are identifying the research, development, and demonstration needs, and defining the roles and responsibilities for multiple organizations. Continued participation in these planning activities will allow NASA to better coordinate its plans for foundational research on aviation biofuels. In addition, NASA will continue to work with the Aeronautics Science and Technology Subcommittee of the National Science and Technology Council to ensure that proper research objectives and goals are coordinated at the highest level.

Conclusion

NASA recognizes the high potential of alternative fuels for the aviation industry from the perspectives of protecting the environment and ensuring the long-term viability of the fuel supply. The Agency has initiated research activities to address some of the major challenges of alternative fuels development, fully recognizing that this is an emerging technology area that will require collaboration on research and development among multiple government agencies, industries, and academia to make biofuels a reality. NASA believes its expertise and research capabilities in combustion, turbine engine performance, fuel processing, materials, and computational modeling can be utilized as part of a nationally coordinated research effort to address some of the key challenges that must be overcome for widespread use of second generation biofuels in future aviation. Such research on biofuels will complement a diverse portfolio of technologies that NASA is working on to improve the efficiency and reduce the environmental impact of aviation in the future.

I would be happy to respond to any questions you or the other Members of the Subcommittee may have.

BIOGRAPHY FOR JAIWON SHIN

Dr. Jaiwon Shin is the NASA Associate Administrator for the Aeronautics Research Mission Directorate. In this position, he manages the agency's aeronautics research portfolio and guides its strategic direction. This portfolio includes research in the fundamental aeronautics of flight, aviation safety and the Nation's airspace system.

Shin co-chairs the National Science & Technology Council's Aeronautics Science & Technology Subcommittee. Comprised of federal departments and agencies that fund aeronautics-related research, the subcommittee wrote the Nation's first presidential policy for aeronautics research and development (R&D). The policy was established by Executive Order 13419 in December 2006 and will guide U.S. aeronautics R&D programs through 2020. The subcommittee finished writing the National Aeronautics R&D Plan in December 2007 and is currently writing the Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan both of which were called for by the Executive Order.

Between May 2004 and January 2008, Shin served as Deputy Associate Administrator for the Aeronautics Research Mission Directorate where he was instrumental in restructuring NASA's aeronautics program to focus on fundamental research and better align with the Nation's Next Generation Air Transportation System (NextGen).

Prior to coming to work at NASA Headquarters, Shin served as Chief of the Aeronautics Projects Office at NASA's Glenn Research Center. In this position he had management responsibility for all of the Center's aeronautics projects. Prior to this he was Glenn's Deputy Director of Aeronautics, where he provided executive leadership for the planning and implementation of Glenn's aeronautics program, and interfaced with NASA Headquarters, other NASA centers, and external customers to explore and develop technologies in aeropropulsion, aviation safety and security, and airspace systems.

Between 1998 and 2002, Shin served as Chief of the Aviation Safety Program Office, as well as the Deputy Program Manager for NASA's Aviation Safety Program and Airspace Systems Program. He assisted both Program Directors in planning and research management.

Dr. Shin received his doctorate in mechanical engineering from the Virginia Polytechnic Institute and State University, Blacksburg, Virginia. His Bachelor's degree is from Yonsei University in Korea and his Master's degree is in mechanical engineering from the California State University, Long Beach. His honors include NASA's Outstanding Leadership Medal, NASA's Exceptional Service Medal, a NASA Group Achievement Award, Lewis Superior Accomplishment Award, three Lewis Group Achievement Awards, and an Air Force Team Award. He is a graduate of the Senior Executive Fellowship Program at the Kennedy School of Government at Harvard University. He has extensive experience in high speed research and icing, and has authored or co-authored more than 20 technical and journal papers.

Chairwoman GIFFORDS. Thank you, Dr. Shin. Dr. Maurice, please.

STATEMENT OF DR. LOURDES Q. MAURICE, CHIEF SCIENTIFIC AND TECHNICAL ADVISOR, OFFICE OF ENVIRONMENT AND ENERGY, FEDERAL AVIATION ADMINISTRATION

Dr. MAURICE. Good morning, Madam Chair, Congressman Olson, Members of the Subcommittee. I welcome the opportunity to testify today about the ongoing work of the FAA and our colleagues on renewable jet fuels.

FAA helped form and is an active participant in Commercial Aviation Alternative Fuels Initiative, or CAAFI. I serve as the Environmental Lead for the group. Founded in 2006, CAAFI is a coalition of airlines, airports, aircraft and engine manufacturers, energy producers, researchers, and U.S. Government agencies that are leading efforts to develop and deploy alternative jet fuels for commercial aviation.

We know environmental and energy issues will significantly influence the ability of our aviation system to grow. Renewable jet fuels could be the game changer technology that gets us closer to carbon neutrality. These fuels could not only improve air quality and reduce life cycle greenhouse gas emissions but also enhance energy security and supplies, and renewable jet fuels are critical to achieving the environmental goals of the next generation air transportation system, or NextGen.

Today's hearing is well-timed. Aviation has made enormous progress in the last three years identifying and testing technologies for alternative fuels and in progressing toward broad air worthiness certification. We have identified a number of options that can replace petroleum jet fuel without the need to modify aircraft, often referred to as drop-in fuels.

CAAFI has taken a comprehensive approach to the development, evaluation and deployment of these drop-in alternative jet fuels. Efforts are focused in four key areas: field certification, research and development, environmental impacts and costs and benefits, and the business and economics of commercialization. Let me highlight a few key points.

The CAAFI environmental team has focused on measuring the potential to reduce aviation greenhouse gases using renewable jet fuels. The FAA and the U.S. Air Force are jointly funding the development of a greenhouse gas life cycle analysis framework. We refer to the approach as well-to-wake. We are also assessing the ability of these fuels to reduce air quality impacts. For example, we recently obtained direct measurements that showed significant particulate matter reductions. This is important because 44 percent of our busiest 50 airports are in areas of non-attainment status for particulate matter emissions.

CAAFI uses R&D roadmaps to align and communicate research needs for alternative fuels. I should note that CAAFI does not sponsor research, per se. Rather, we try to ensure a coordinated approach to strengthen each other's efforts and avoid duplication. We have submitted copies of the roadmap with my written testimony and would welcome your input.

With regard to how alternative fuels will actually be introduced for use, the FAA collaborates with ASTM International, the industrial standard-setting organization, to perform the technical evaluation of potential alternative jet fuels leading to FAA air worthiness certification. The process adheres to strict rules and standards to ensure safety. We anticipate approval for a generic standard for a range of fuels from Fisher-Tropsch processes including biomass-to-liquid fuels for use at a 50 percent level this year. Similarly, we forecast approval for use by as early as the end of 2010 of hydroprocessed renewable jet derived from non-food biomass feedstocks. This potential approval relies on recent data but may also require additional investment in research.

A number of significant challenges remain. First and foremost is certification. We believe we have a path for achieving renewable jet fuel approval. However, approval would require significant amounts of alternative fuels and engine tests and evaluation. There can be no shortcuts to safety.

Next is the challenge of accurately quantifying environmental impacts. Assessment of both air quality and greenhouse gas life cycle emissions must continue to be timely and thorough as new options emerge. This will also require significant effort and the collaboration of all stakeholders involved. Supporting certification and environmental impacts assessments are a major focus of FAA's CLEEN program, and we appreciate the Subcommittee's support for these efforts.

The final hurdle is infrastructure and deployment. The unique combination of dependence on high-density liquid hydrocarbon fuels for the foreseeable future and a very condensed infrastructure, about 80 percent of all jet fuel used at our 35 busiest airports, makes aviation both difficult and attractive for pursuing alternative fuels. We are convinced that the public/private partnership that CAAFI represents will help commercial aviation be a first mover in the deployment of alternative fuels.

Madam Chair, Members of the Subcommittee, that completes my prepared remarks, and I look forward to your questions.

[The prepared statement of Dr. Maurice follows:]

PREPARED STATEMENT OF LOURDES Q. MAURICE

Madam Chair, Congressman Olson, and Members of the Subcommittee:

Thank you for the invitation to testify on "Aviation and the Emerging Use of Biofuels." I am the Federal Aviation Administration's (FAA) Chief Scientific and Technical Advisor for Environment and Energy. In that role I also serve as the environmental team leader for the Commercial Aviation Alternative Fuels Initiative (CAAFI). I am pleased to be able to speak to the Subcommittee today about biofuel (hereinafter referred to as "renewable jet fuel") activities of CAAFI.

Today's hearing is well timed. Aviation has made enormous progress in the last three years identifying and testing technologies for renewable jet fuels, and progressing toward broad airworthiness certification for the most mature of these technologies. As you may know, the FAA has the responsibility to make sure that any aircraft, aircraft engine or part, or fuel that is used in aviation is safe and performs to set standards. We have identified a number of alternative jet fuels (including renewable jet fuels) that can replace petroleum jet fuel without the need to modify aircraft, engines and fueling infrastructure (often referred to as "drop-in" fuels). Compared to the other transportation sectors, aviation is, in fact, well positioned to adopt renewable jet fuels. Moreover, this effort is critical to achieving the environmental goals of the Next Generation Air Transportation System (NextGen).

In order to spur deployment of fuels with clear environmental benefits we are aggressively pursuing robust and reliable environmental life cycle analysis to quantify environmental impacts of renewable jet fuels, including air quality and greenhouse (GHG) impacts from direct and indirect land use change, feedstock production, fuel processing, transport and use in aircraft. We are coordinating this aviation effort with the Environmental Protection Agency's (EPA) life cycle analysis through an interagency working group. Airlines and multiple fuel suppliers are developing a range of opportunities to deploy renewable jet fuels and are pursuing deployment options via incentives available from U.S. Department of Energy (DOE) and U.S. Department of Agriculture (USDA) programs on, for the first time, an equal basis with ground transportation users. And because safety is crucial to this effort, FAA is taking the certification process step-by-step to ensure that any fuels developed will meet or exceed the safety performance of today's jet fuels. FAA will also ensure, in collaboration with EPA, that any new fuels will meet or exceed emissions standards for aircraft engines.

While the aviation community has made significant strides, we have learned as we have worked on this effort, as is the case with most new technical initiatives. There are ongoing efforts now that we did not imagine at the outset. One example is the rapid pace of development and flight testing of hydroprocessed renewable jet fuels. However, it is clear there is no one "silver bullet" global process or feedstock solution. Rather there are multiple solutions, which we can pursue in an environmentally and economically viable and safe manner via regional development and deployment.

Founded in 2006, CAAFI[1] is a coalition of airlines, airports, aircraft and engine manufacturers, energy producers, researchers and U.S. Government agencies (including FAA, EPA, USAF, NASA, DOE and USDA) that are leading efforts to develop and deploy alternative jet fuels for commercial aviation. Jointly sponsored by the FAA, the Air Transport Association of America, the Aerospace Industries Association and Airports Council International-North America, CAAFI has taken a comprehensive approach to the development, evaluation and deployment of alternative jet fuels. CAAFI focuses its stakeholder efforts in four key areas: fuel certification, research and development (R&D) needs, environmental impacts and costs and benefits, and the business and economics of commercialization. The goal is to promote the development of renewable jet fuels for use with today's aircraft fleet that offer equivalent or better cost compared to petroleum based jet fuel, with equivalent safety. Further, the goals are also to provide environmental improvement, energy supply security and economic development. Promising renewable jet fuel feedstocks options may include biomass, corn-stover, and inedible crops such as jatropha and camellina, and algal oils.

In your invitation to testify, the Subcommittee asked me to specifically address the following five questions regarding emerging aviation renewable jet fuels:

1. *What research is CAAFI sponsoring or coordinating to validate the projected benefits of using biofuel in civil aviation in terms of their ability to reduce engine emissions?*

First I should clarify that CAAFI does not sponsor research per se. Rather we are a coalition of stakeholders that individually and collectively sponsor and coordinate research to meet CAAFI's goals. This ensures we strengthen each other's efforts and avoid duplication. One of the goals of CAAFI's environmental team is quantifying the potential for renewable jet fuels and renewable jet fuel blends to improve air quality and reduce life cycle GHG emissions. An improved environmental footprint is a critical objective of alternative jet fuels (including renewable jet fuels) for both the FAA and other CAAFI sponsors. Largely funded by FAA, the CAAFI environmental team's efforts in air quality include both the measurement of engine exhaust emissions such as particulate matter and sulfur oxides and calculating the cost and benefits of reducing these emissions with alternative fuels. The FAA funded efforts totaling $1 million in fiscal[2] year 2008 through the Partnership for AiR Transportation Noise and Emission Reduction (PARTNER) Center of Excellence focused on assessing select air quality emissions for alternative fuels including renewable jet fuels: Emissions Characteristics of Alternative Aviation Fuels and Ultra Low Sulfur (ULS) Jet Fuel Environmental Cost Benefit Analysis.[3]

The U.S. has National Ambient Air Quality Standards for particulate matter emissions and 44 percent of our 50 largest airports in terms of enplanements are in areas of non-attainment status for these emissions. Common to all alternative fuels under consideration is their potential to reduce particulate matter emissions. We have obtained direct measurements in in-service aircraft engines that clearly

[1] The CAAFI coalition includes 300 domestic and international stakeholder representatives: U.S. Government agencies, aircraft and engine manufacturers, over 40 energy producers, many of the world's airlines, and numerous Universities.

[2] In fiscal year 2009, we expect to invest approximately $2 million in alternative jet fuels (including renewable jet fuels).

[3] More information about PARTNER is available at *http://web.mit.edu/aeroastro/partner/projects/index.html*

validate these benefits.[4] Additionally, with CAAFI's support, the FAA-sponsored Transportation Research Board's Airport Cooperative Research Program (ACRP) will complete in May 2009 a handbook enabling possible investors, airlines and airports to quantify environmental and/or financial gains for alternative jet fuel (including renewable jet fuel) use at their specific airports.[5]

The consideration of the life cycle emissions from alternative fuel production and transportation must be considered when calculating environmental impacts and the CAAFI environmental team has also focused on measuring the potential to reduce aviation GHG emissions by using renewable jet fuels. For example, the FAA and the U.S. Air Force are jointly funding the development of a GHG life cycle analysis (LCA) framework through the FAA's PARTNER Center of Excellence.[6] We refer to the approach as "well-to-wake." The CAAFI environmental team endorsed the intent to develop a consistent framework in October 2008. The Intergovernmental Panel on Climate Change (IPCC)-endorsed global aviation emissions modeling tools anchor the framework on the aircraft exhaust end. To measure GHG emissions from the production end, CAAFI researchers are part of a working group (including FAA, U.S. Air Force, DOE, EPA, and university experts) that is developing best practice tools to capture the many variables associated with GHG life cycle calculation. At the present time a half dozen domestic and international alternative jet fuel producers are participating with CAAFI and can evaluate the outcomes of their specific projects using this framework.

Once completed, we will rigorously peer review the LCA framework to ensure it is based on the best science and accurately captures GHG life cycle emissions to inform the aviation industry and potential fuel producers.

2. *What is the status of CAAFI's roadmap? How does CAAFI ensure that federal and private sector biofuel research is aligned?*

CAAFI uses R&D roadmaps to align and communicate research needs that will define both process and feedstock maturity up to certification and subsequently through deployment. On January 27 CAAFI's R&D team, hosted by the U.S. Air Force in Dayton, OH, updated the R&D roadmaps. Participants contributing to this process included government technology investors such as the National Aeronautics and Space Administration (NASA), DOE's National Renewable Energy Labs and Energy Efficiency and Renewable Energy office, and USDA, as well as private sector investors. The resulting roadmaps define the work done to date, and what's planned or needed to support deployment of alternative aviation fuels. These updated roadmaps include milestones for maturing feedstock and production processes for renewable jet fuels. The roadmaps are currently available in draft form; stakeholders as well as government, and any other entities concerned about aviation alternative fuels, can use the roadmaps in their final form to guide investment decisions. CAAFI welcomes the Subcommittee's participation in both using and contributing to these roadmaps (see Appendix A).

3. *Can the development readiness of various biofuels be commonly characterized and measured?*

As a complement to communicating research needs, we also need a common definition of alternative fuels among all fuel investors and aviation consumers to determine the maturity of the variety of alternative options that are under considerations. Such a system helps to differentiate candidates in the research phase (such as those being pursued by NASA and the Defense Advanced Research Projects Agency (DARPA)), candidates ready for certification, and candidates in the deployment phase and worthy of support by private investors and public funding such as that by the USDA Rural Development program. On January 27, 2009, CAAFI introduced a risk management measuring system for alternative fuels named Fuel Readiness Level (FRL). The basis of FRL is the Technology Readiness Level (TRL) used by the U.S. Air Force, NASA and CAAFI's manufacturing sector to classify systems development maturity. FRL combines TRL with critical manufacturing readiness level (MRL) steps to characterize the readiness of alternative fuel candidates. As is

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[4] Hileman, J., Ortiz, D., Brown, N., Maurice, L., and Rumizen, R., "The Feasibility and Potential Environmental Benefits of Alternative Fuels for Commercial Aviation," International Congress of Aeronautical Sciences, Anchorage, Alaska, September 2008.

[5] See ACRP Project 02–07: Handbook for Analyzing the Costs and Benefits of Alternative Turbine Engine Fuels at Airports. See *http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1585*

[6] For work to develop alternative jet fuel life cycle analyses, see PARTNER Center of Excellence Project 17: Alternative Jet Fuels and Project 28: Alternative Jet Fuel Environmental Cost Benefit Analysis at *http://web.mit.edu/aeroastro/partner/projects/index.html*

the case with CAAFI's roadmaps, FRL protocols are available to the Subcommittee (see Appendix B).

4. What research is CAAFI sponsoring or coordinating to determine the impact that long-term and widespread biofuel use may have on aircraft safety, and engine performance/maintainability/reliability? Is more research needed? In what areas?

The FAA (through CAAFI) collaborates with ASTM International, the industrial standards-setting organization, to perform the technical evaluation of potential alternative jet fuels leading to FAA airworthiness certification. The process adheres to strict rules and standards to ensure safety. The CAAFI certification team comprises core members of that body representing equipment manufacturer, fuel producer, and fuel consumer sectors. My colleague Mark Rumizen of the FAA's Airworthiness division chairs the CAAFI certification team. The certification team's goal is to facilitate fuel certification for alternative jet fuels by coordinating the fuel evaluation and specification development process with airworthiness authorities and industry stakeholders. The team is initially focused on, as noted above, "drop-in" fuels. These fuels are essentially identical to conventional Jet A and transparent to the aircraft system and aviation fuel infrastructure. Equivalent operating performance and maintenance characteristics are inherent in the definition of "drop-in" fuel.

Simply meeting top-level specification requirements for airworthiness (for example freeze point, flash point and energy content) is not sufficient for fuel approval. ASTM uses testing protocols developed by a special ASTM task force to ensure no changes in operating and maintenance characteristics. For example the "fit for purpose" testing puts bounds on lubricity requirements that will influence fuel system wear. Testing identifies a minimum aromatic content to ensure elastomer seals perform properly. Limits on electrical conductivity of the fuel ensure that there is no interference with cockpit instrumentation.[7]

Presently CAAFI's certification team and ASTM are completing a framework specification for synthetic alternatives to complement the petroleum-based specification. ASTM members are currently reviewing this new specification approach for approval. With the new specification, we expect a generic approval of the full range of fuels from Fischer-Tropsch (F–T) processes[8]—including biomass to liquid fuels—for use at a 50 percent blend level.[9] Similarly, we forecast approval for use by as early as the end of 2010 of hydroprocessed renewable jet (HRJ) fuel—from non-food biomass feedstocks such as corn stover, jatropha, camelina, halophytes and algae. This probable approval relies on recent data but may also require additional investment in research. The FAA's Continuous Low Emissions, Noise and Energy (CLEEN) program is one source for this investment. Flight tests sponsored by industry will also support the certification efforts.

5. In CAAFI's view, what are the main challenges facing widespread use of biofuels in civil aviation? What issues need to be resolved before CAAFI can project when widespread aviation use of biofuels may occur?

Speaking as a member of CAAFI, we view three areas as hurdles, as well as opportunities for future focus:

First and foremost is certification. We believe we have a path for achieving biofuel approvals at a 50 percent blend level over the next two years. However, approval of the blend and eventual approval of 100 percent renewable jet fuels may require full combustor rig and or engine tests under approval protocols. We can leverage U.S. Air Force investment in biofuel testing to cover the performance of in-use commercial engines such as on the C–17 aircraft. However, we will likely need additional testing to cover advanced low emissions combustors such as those on new commercial engines or advanced cycles such as those NASA is exploring. Full combustor rig and engine tests require as much as 250,000 gallons of fuel, which may be a significant challenge for some candidate alternative fuel producers, as well as requiring substantial research investment.

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[7] Much of the fit for purpose testing is being done by the U.S. Air Force and then shared with CAAFI.

[8] The Fischer-Tropsch or F–T synthetic fuel production process is a catalyzed chemical reaction in which synthesis gas, a mixture of carbon monoxide and hydrogen, is converted into liquid hydrocarbons of various forms. This output produces synthetic petroleum replacements such as diesel and jet fuel from coal, natural gas or biomass.

[9] One F–T fuel made by SASOL of South Africa is already approved for global aviation use at a 50 percent and 100 percent blend. However this approval is for one specific manufacturer, with one specific feedstock and one specific facility. CAAFI is targeting a generic specification that will enable approval of many different manufacturers, feedstocks and facilities that use this process.

The next hurdle is accurately quantifying environmental impacts. Assessments of both air quality and GHG life cycle emissions impacts must continue to be timely and thorough as new fuel options emerge. For example, we, in collaboration with EPA, need to populate emissions prediction models with measured emissions data for emerging renewable jet fuels. Acquiring such data is empirical in nature and requires significant testing and investment. Reducing the uncertainties associated with land use changes, fertilizer use, and impacts on the quality and quantity of water resources, GHG inherent in-life cycle analyses from harvest to processing to transport and use of the renewable jet fuels, will also require significant effort and investment, and the collaboration of all stakeholders involved to ensure an agreeable and accurate framework.

The FAA's CLEEN program, noted above, as well as its NextGen investments in environment and energy research, are vehicles available to CAAFI sponsors and other stakeholders to address the certification and environmental issues. We appreciate the Subcommittee's support for these efforts.

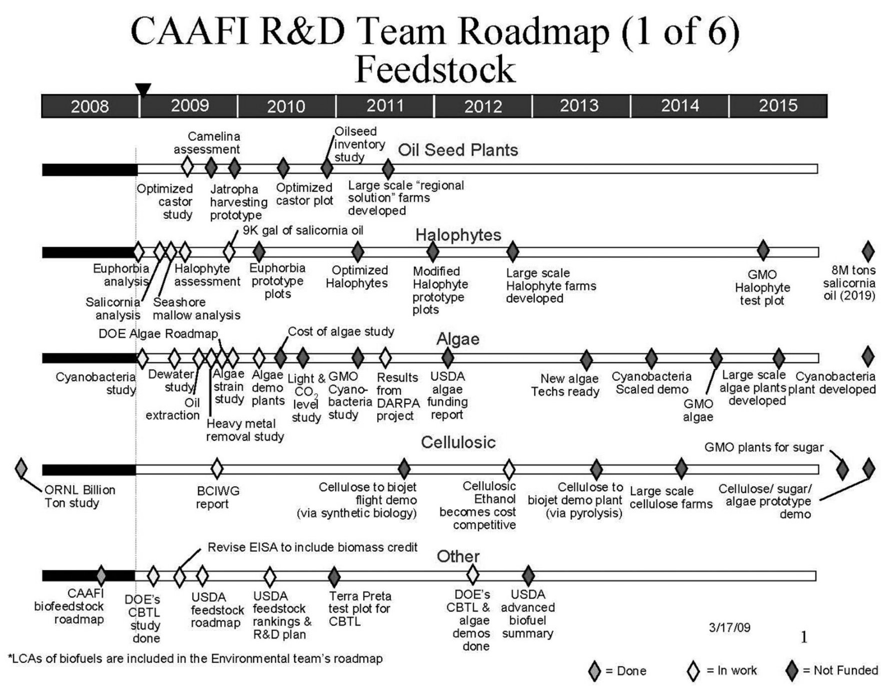
The final hurdles are infrastructure and deployment. Aviation's dependence on high-density liquid hydrocarbon fuels for the foreseeable future is perhaps unique, unlike surface transportation modes which have other options such as electric power and lower-density ethanol fuel. Another unique characteristic of U.S. commercial aviation is that the fueling infrastructure can serve over 80 percent of all jet fuel used in about 35 locations, i.e., at our busiest airports. These realities of dependence and concentrated infrastructure should lead to aviation becoming a "first mover" in the deployment of alternative fuels. Aviation's circumstances are critical to its attractiveness to biofuel producers despite aviation's small market for transportation fuels relative to cars and trucks.

The recent economic slowdown has somewhat diminished the ability of conventional investment sources to quickly respond to the opportunities that aviation uniquely provides. However, FAA believes there is a need for investments in biofuel production infrastructure specific to aviation. With relatively modest investment at locations near airports which combine feedstock availability, existing biofuel infrastructure, need for air quality gains, and U.S. airlines eager to use renewable jet fuels, we believe successful production facilities can be built. Focusing sufficient investment on developing a number of success models, rather than a target percentage of fuel supply from renewable jet fuels, is likely the key to producers deploying these fuels for both the aviation industry and perhaps the Nation as a whole.

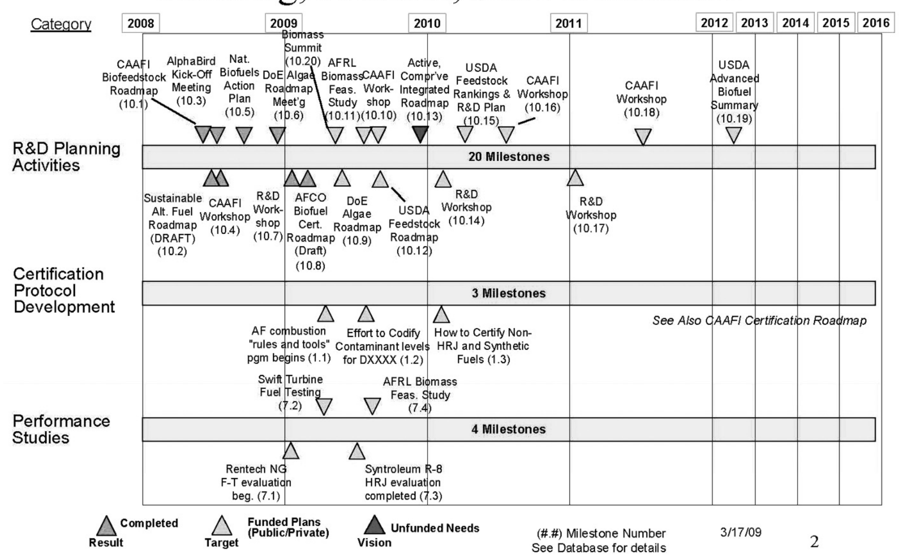
The Nation has often counted upon the skills of the aerospace industry to lead the way in technical innovation. Renewable jet fuels offer the opportunity to team the aerospace science and technology efforts with those of agriculture, energy, and sustainability to address the three challenges I outlined above.

Madam Chair and Members of the Subcommittee, thank you again for the opportunity to testify on how the aviation community is leading the way to develop and realize the potential of emerging aviation renewable jet fuels. That completes my prepared remarks and I welcome any questions that you may have.

Appendix A: CAAFI R&D Roadmaps

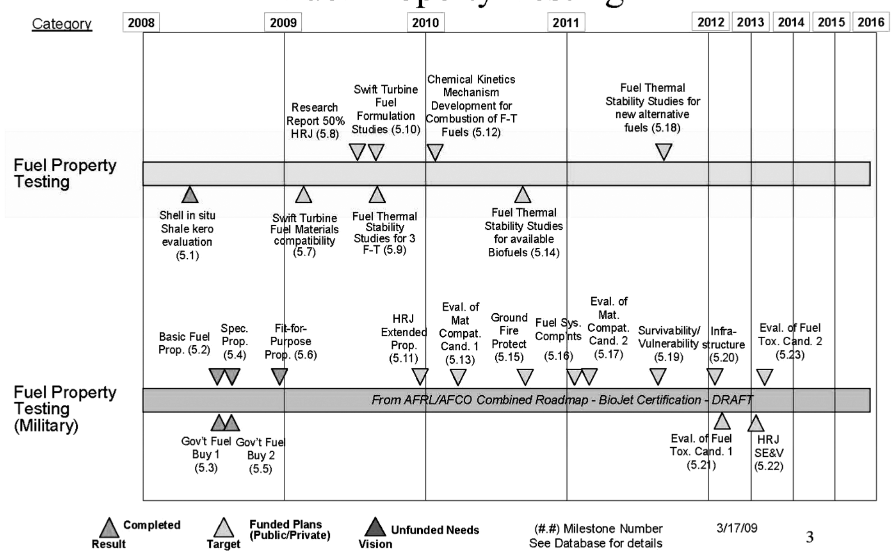


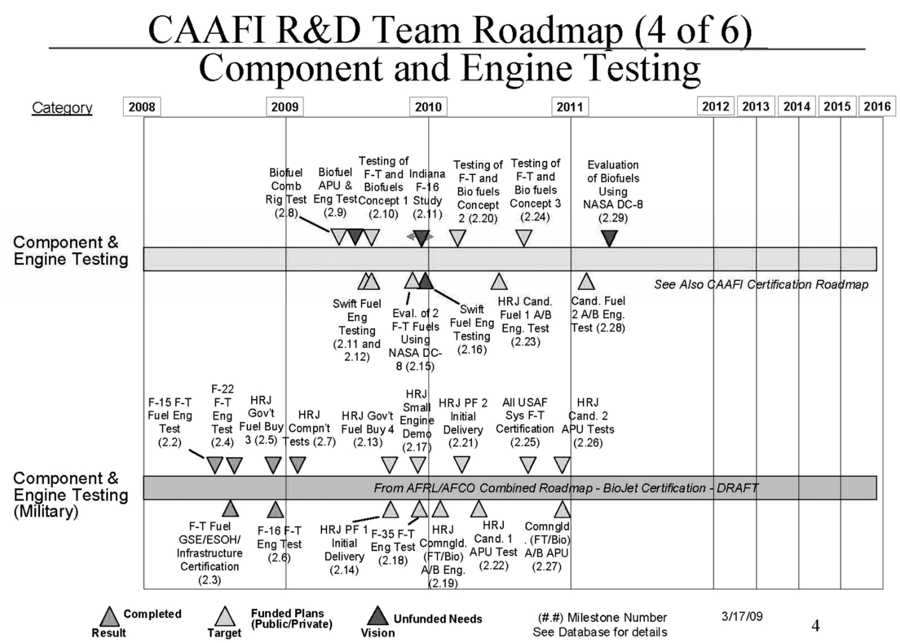
CAAFI R&D Team Roadmap (2 of 6)
Planning, Protocol, and Performance



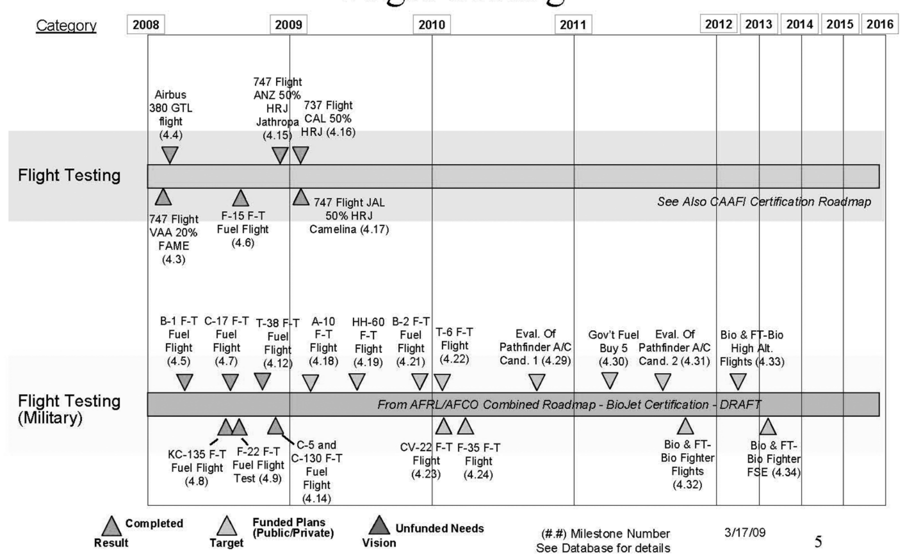
CAAFI R&D Team Roadmap (3 of 6)

Fuel Property Testing

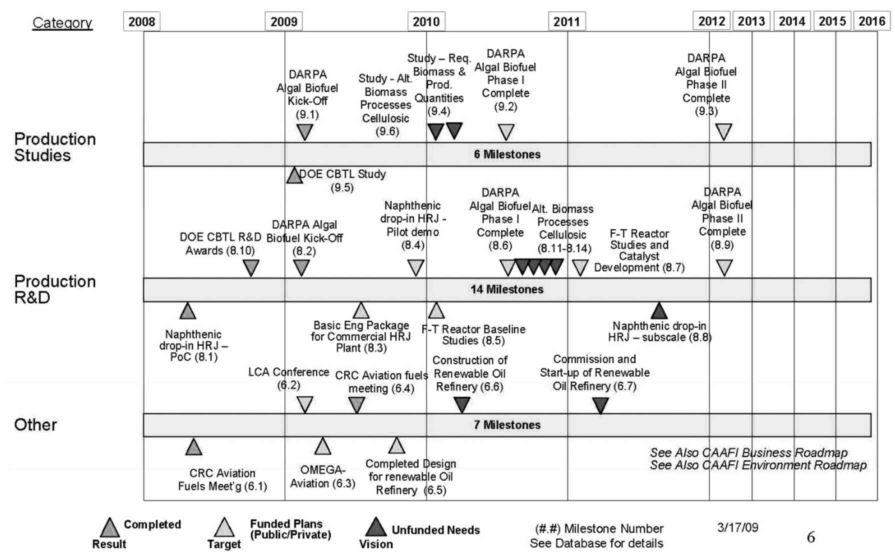



CAAFI R&D Team Roadmap (4 of 6)
Component and Engine Testing
Category
2008
2009
2010
2011
2012
2013
2014
2015
2016
Component & Engine Testing
Biofuel Comb Rig Test (2.8)
Biofuel APU & Eng Test (2.9)
Testing of F-T and Biofuels Concept 1 (2.10)
Indiana F-16 Study (2.11)
Testing of F-T and Bio fuels Concept 2 (2.20)
Testing of F-T and Bio fuels Concept 3 (2.24)
Evaluation of Biofuels Using NASA DC-8 (2.29)
Swift Fuel Eng Testing (2.11 and 2.12)
Eval. of 2 F-T Fuels Using NASA DC-8 (2.15)
Swift Fuel Eng Testing (2.16)
HRJ Cand. Fuel 1 A/B Eng. Test (2.23)
Cand. Fuel 2 A/B Eng. Test (2.28)
See Also CAAFI Certification Roadmap
Component & Engine Testing (Military)
F-15 F-T Fuel Eng Test (2.2)
F-22 F-T Eng Test (2.4)
HRJ Gov't Fuel Buy 3 (2.5)
HRJ Compn't Tests (2.7)
HRJ Gov't Fuel Buy 4 (2.13)
HRJ Small Engine Demo (2.17)
HRJ PF 2 Initial Delivery (2.21)
All USAF Sys F-T Certification (2.25)
HRJ Cand. 2 APU Tests (2.26)
From AFRL/AFCO Combined Roadmap - BioJet Certification - DRAFT
F-T Fuel GSE/ESOH/ Infrastructure Certification (2.3)
F-16 F-T Eng Test (2.6)
HRJ PF 1 Initial Delivery (2.14)
F-35 F-T Eng Test (2.18)
HRJ Comngld. (FT/Bio) A/B Eng. (2.19)
HRJ Cand. 1 APU Test (2.22)
Comngld. (FT/Bio) A/B APU (2.27)
Completed Result
Funded Plans (Public/Private) Target
Unfunded Needs Vision
(#.#) Milestone Number See Database for details
3/17/09
4

CAAFI R&D Team Roadmap (5 of 6)
Flight Testing



CAAFI R&D Team Roadmap (6 of 6)
Production Studies and R&D



Supplement to CAAFI R&D Team Roadmap
Feedstock Roadmap Milestone Description

The following text provides descriptions for each of the milestones listed on the Commercial Aviation Alternative Fuel Initiative (CAAFI) R&D Feedstock Roadmap.

Swimlane #1: OIL SEED PLANTS.
(Plants whose seeds contain oil that is suitable for biofuel)

Optimized Castor Study (In Work): A modified Castor plant with about 2X the oil yield of present Castor plants has been developed in the lab and will be tested in large scale plots in Brazil (see below). This could provide biofuel for near-term applications.

Camelina Assessment (Unfunded): This feedstock appears promising for present biofuel applications using fallow farmland in North America. A Life Cycle Assessment needs to be performed.

Jatropha Harvesting Prototype (Unfunded): Jatropha appears promising for near-term oil production without competing for farmland or irrigated fresh water. However, the plant's oil seed currently needs to be harvested by hand, and an automated process needs to be developed to reduce production costs and reduce human contact with the poisonous plant.

Optimized Castor Plot (Funded): The resulting modified optimized castor plant (see above) will be planted in a large scale test plot in Brazil to validate productivity.

Oilseed Inventory Study (Unfunded): The USDA is wishing to perform a study that accurately describes the various oil seed crops, their performance, and the rate at which such plants could be scaled up for commercial production.

Large Scale "Regional Solution" Farms Developed (Unfunded): It is anticipated that there will not be one bio-feedstock for world-wide production of biofuel, but there will be multiple solutions, depending on the political-techno and geographic location. Large scale farms are thought to be developed that are suitable for each region of the world.

Swimlane #2: HALOPHYTES
(Salt water tolerant plants that could also yield oil.)

Euphorbia Analysis (In Work): Research into the plant Euphorbia Tirucalli (commonly known as the petroleum plant) for possible development as a feedstock for biofuels. The plant is undergoing preliminary evaluation for its salt water tolerance and is being grown in desert areas.

Salicornia Analysis (In Work): A life cycle analysis of the Salicornia plant, which produces both food and fuel. Development work is primarily being conducted by Global Seawater Foundation.

Seashore Mallow Analysis (In Work): Seashore mallow could fill a niche as a biofuel feedstock as the plant's architecture and oil yield are similar to soybeans. Perhaps even more appealing, is that the plant thrives in salty soils where nothing else will grow. In fact, the plant can be irrigated with saltwater. Limited research is under way to evaluate this crop for North American applications.

Halophyte Assessment (In Work): An analysis of various halophytes for their potential to produce bio-oils in various parts of the world and the scale up potential. Various research organizations are conducting work on specific varieties, but a coordinated assessment effort is needed to bring all the results together for analysis.

Euphorbia Prototype Plots (Unfunded): Larger scale test plots of various plants to verify the yield per acre under various growing conditions.

Optimized Halophytes (Unfunded): Plants that have undergone high throughput nursery breeding techniques to increase their oil level as well as other desirable growing characteristics.

Modified Halophyte Prototype Plots (Unfunded): Larger scale test plots of the above plants to verify growth rates and oil yield.

Large Scale Halophyte Farms Developed (Unfunded): Commercialization of the above modified Halophyte plants.

GMO Halophyte test plot (Unfunded): Genetically modified versions of the above halophyte plants to specifically further improve its oil yield.

8 Tons Salicornia Oil (Unfunded): Expected bio-oil output of large scale test farms, such as Global Seawater Foundation.

Swimlane #3: ALGAE

(Macro & Micro salt and fresh water organisms having oil content)

Cyanobacteria Study (In Work): A study to evaluate if cyanobacteria, which are faster growing and hardier than algae, can be genetically modified to produce oil and grown in photobioreactors to economically produce biofuel.

Dewater Study (In Work): Several researcher are evaluating how to economically separate the small amount of algal biomass (typically < 0.1 percent) contained in the large amount of water (>99.9 percent) used for growing.

Oil Extraction (In Work): Research into how to break down the algae cell walls and economically extract oil from various algae strains in a production type setting.

Heavy Metal Removal (In Work): Ways to economically remove the heavy metals that can be found in algae grown in waster water and/or with coal flue gas. These metals would poison the fuel processing catalysts used at fuel refineries.

DOE Algae Roadmap (In Work): DOE is developing an algae biofuels roadmap. Draft expected to be completed for intra-government review in Fall 2009.

Algae Strain Study (In Work): Of the 40,000 different algal strains that are believed to exist in the world, research the additional strains (beyond the 3,000 varieties) that were studied in the Aquatic Species Program.

Algae Demo Plants (In Work): Numerous scaled algae demonstration plants are claimed to be in development around the world. Seambiotic, in Israel, is one such prototype plant known to be currently producing algae using flue gas.

Cost of Algae Study (Unfunded): A detailed economic study to assess the economic viability of algae to compete with fossil fuels. It is believe that an integrated production approach, that also utilizes valuable algae co-products, will be required.

Light & CO_2 level study (Unfunded): Some previous work has been performed on limited algal strains to assess their growth characteristics under varying light and CO_2 levels, but more studies would be required for the optimal algae strains yet to be discovered.

GMO Cyanobacteria Study (Unfunded): A more in-depth study (from above) to evaluate the probability and cost of developing a genetically modified cyanobacteria that has oil producing characteristics.

Results from DARPA project (In Work): The goal of this multi-million dollar program (BAA 08–07) is to develop the technical capability and commercial experience to produce an affordable JP–8 (i.e., military version of commercial Jet-A fuel) surrogate fuel from algae.

USDA algae funding report (Unfunded): A report summarizing the R&D taking place for algae.

New Algae Techs Ready (Unfunded): The assumed breakthrough technologies are developed to address the: optimal algal strains, dewatering, harvesting and oil extraction challenges that remain for this technology to become economically competitive with fossil fuels.

Cyanobacteria Scaled Demo (Unfunded): A scaled demonstration version of the GMO cyanobacteria that was developed (see above).

GMO Algae (Unfunded): Genetically modified algae organisms are developed that have: much higher oil content, resistance to invading algae species and grazers, higher productivity, high culture stability and auto-bioflocculation tendencies.

Large Scale Algae Plants Developed (Unfunded): After the technical and economic breakthroughs are achieved, it is envisioned that vary large scale algal farms will be developed to start commercial operation of algae oil for biofuel.

Cyanobacteria Plant Developed (Unfunded): If the GMO cyanobacteria can be developed, economically produced and is socially acceptable, it is envisioned that this hardier and higher productivity organism may displace algae as the main oil producing biofeedstock.

Swimlane #4: CELLULOSE FEEDSTOCKS

Billion Ton Study (Completed): Report conducted by DOE's Oak Ridge National Lab (ORNL) on "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply." It showed that 1.3B tons/year of biomass could be harvested to meet one-third of U.S. fuel needs by 2030.

BCIWG Report (In Work): The Biomass R&D Board Biomass Conversion Interagency Working Group (BCIWG). The Biomass Research and Development Board established an interagency working group to guide the exploration of cost effective commercially viable processes for converting cullulosic and other biomass to biofuels (ethanol, higher alcohols, and green gasoline, diesel, and aviation fuels). The group is comprised of NSF, DOE, USDA, EPA and DOD and other agencies. The BCIWG is authoring a 10-year Federal RD&D biomass conversion plan report.

Cellulose to biojet flight demo (Not Funded): A flight demonstration of a biojet fuel made from cellulose via enzymatic deconstruction and synthetic biology buildup of pure hydrocarbon molecules (alkanes).

Cellulosic Ethanol becomes cost competitive (Funded): A (hoped for) milestone where sufficient R&D has overcome the cost hurdles in making commercial ethanol production less expensive when using a cellulosic conversion processes versus the conventional corn starch method.

Cellulose to biojet demo plant via pyrolysis (Not Funded): A small demonstration plant that more efficiently converts cellulosic material into a bio-crude oil that can then be fed into conventional oil refineries for processing.

Cellulose/Sugar/Algae Prototype Demo (Not Funded): Sugars that are derived from hemicellulose from woody plants can be used as nutrients to rapidly grow algae in non-sunlight reactors (i.e., heterotrophic conditions). Heterotrophic growth of algae on pentose sugars from hemicellulose may be a promising approach for algae production as it would not compete with either food sugar or ethanol sugars, which are all hexose sugars.

Large scale cellulose farms (Not Funded): Initial commercialization of prairie grasslands that are (no till) seeded with switchgrass and harvested with no environmental damage.

GMO plants for easy sugar conversion (In Work): Genetically modified plants, such as poplar trees, that have enhanced growth characteristics such that processing enzymes may more easily break down the lignin for conversion into sugars.

Swimlane #5: OTHER FEEDSTOCKS

(All other plants not covered above.)

DOE's CBTL study done (In Work): A Coal & Biomass To Liquid (CBTL) study where biomass is used to offset CO_2 emissions that would normally be environmentally prohibitive in a conventional Coal To Liquid (CTL) fuel production plant.

Revise EISA to include biomass credit (In Work): The present Energy Independence Security Act (EISA) presently does give environmental credit for using some types of biofeedstocks in certain fuel processing methodologies (e.g., bio-oil used in an oil refinery to make a biofuel/fossil fuel mixture).

Overall Feedstock Assessment (Unfunded): A study to evaluate all other known types of bio-feedstocks (e.g., switchgrass to alkane hydrocarbons through synthetic biology) that could be used to produce biofuel for aviation.

Various Scaled Test Plots (Unfunded): The growing of emerging bio-feedstocks (see above) that could be used for biojet fuel.

Terra Preta Test Plot for CBTL (Unfunded): A scaled agricultural project where the excess solid carbon from the CBTL process is buried in farm plots to evaluate the effect on crop production.

DOE's CBTL & Algae Demos Done (Unfunded): A NETL demonstration project with APS (Arizona Public Supply) where coal is gasified for power generation and algae are grown with flue gas effluent to capture and utilize the CO_2.

Large Scale Cellulose Farms for synthetic biofuel & CBTL (Unfunded): After the fuel processing technologies are developed that can economically convert cellulose into biofuels, it is envisioned that large scale (prairie?) farms will be developed to grow cellulose (e.g., switchgrass, etc.).

Swimlane #5: OTHER
(Primarily activities to coordinate with.)

CAAFI biofeedstock roadmap (Done): This roadmap which was developed on January 27th in Dayton, Ohio by 80 representatives from the aviation, biofuel and feedstock industries.

USDA Feedstock Roadmap (Unknown): It is thought that the USDA should develop its own feedstock R&D roadmap, which would include recommendations from this feedstock roadmap.

USDA Feedstock Rankings and R&D Plan (Unknown): Once the roadmap is developed, funding should be secured for future projects that are underfunded or unfunded, based on their ranked importance to provide biofuel feedstocks for aviation as well as ground transportation. The R&D plan will lay out a formula to achieve U.S. energy independence with help from carbon neutral biofuels.

USDA Advanced Biofuel Summary (Unfunded): A final summary report published by the USDA reviewing all of the next generation feedstocks that could be used for making biofuel and making recommendations.

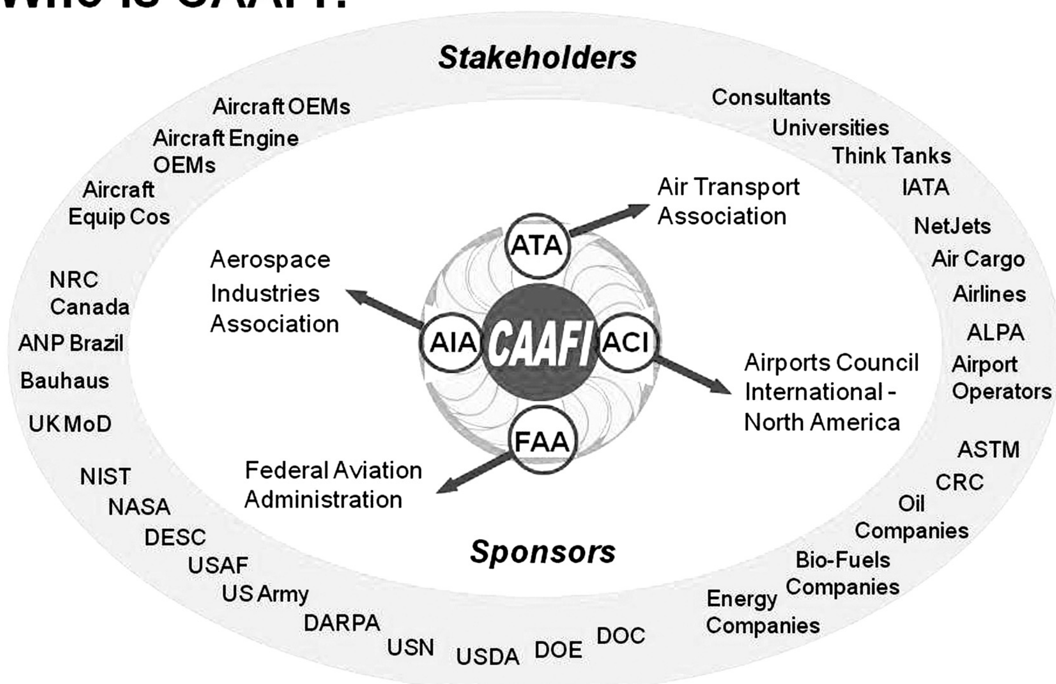
Appendix B: Fuel Readiness Level

Commercial Fuel Readiness Level (FRL) - Alternative Aviation Fuels

FRL	Description	CAAFI Toll Gate	FRL	Description	CAAFI Toll Gate	Fuel Qty	MRL	USAF TRL
1	Basic Principles Observed and Reported	Feedstock and process basic principles identified					1	
2	Technology Concept Formulated	Feedstock and complete process concept identified					2	
3	Proof of Concept	Small Fuel Sample Available from Lab Basic Fuel Properties Validated (Thermal Stability/Freezing Point)				500 ml	3	1. Basic Fuel Properties Observed and Reported
4.1 4.2	Preliminary Technical Evaluation	System Perf. & Integration Studies Entry Criteria/Specification Properties Evaluated (MSDS/D1655/MIL 83133)				10 gal	4	2. Fuel Specification Properties
5.1 5.2 5.3 5.4	Process Validation	Laboratory Production Development Subscale Production Demonstrated Scalability of Production Demonstrated Pilot Plant Capability Enabled	6.1 6.2 6.3 6.4	Full-Scale Technical Evaluation	Fit-For-Purpose Prop's Evaluated Turbine Hot Section Component/Rig/Emissions Testing Engine/APU Testing	80 gal 4K gal 20K gal 225K gal	5 6 7 8	3. Fit for Purpose 4. Extended Lab Fuel Property Test 5. Component Rig Testing 6. Small Engine Testing
			6.5					7. Pathfinder
			7	Fuel Approval	Fuel Class/Type Listed in Int'l Fuel Standards			8. Validation/Certification 9. Field Service Evaluations
8	Commercialization Validated	Business Model Validated for Production Go-Ahead Airline/Military Purchase Agreements						
9	Production Capability Established	Full Scale Plant Operational					9-10	

Legend:	R & D	Certification/Qualification	Business & Economics

Who is CAAFI?



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Dr. Lourdes Maurice

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BIOGRAPHY FOR LOURDES Q. MAURICE

DR. LOURDES Q. MAURICE is the Chief Scientific and Technical Advisor for Environment in the Federal Aviation Administration's Office of Environment and Energy. She serves as the agency technical expert for basic and exploratory research, and advanced technology development focused on aircraft environmental impacts and its application to noise and emissions certification and policy, and the application of alternative fuels to mitigate environmental impacts and enhance energy security. Lourdes manages and provides agency technical leadership for the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence. She previously served as the Air Force Deputy, Basic Research Sciences and Propulsion Science and Technology in the office of the Deputy Associate Secretary of the Air Force for Science and Technology. She also worked at the Air Force Research Laboratory's Propulsion and Power Directorate from 1983 to 1999 planning and executing basic, exploratory, and advanced development propulsion science and technology programs, focusing on state-of-the-art aviation fuels and propulsion systems. Her areas of expertise include pollutant formation chemistry, combustion kinetics, hypersonic propulsion, and aviation fuels. She received her B.Sc. in Chemical Engineering and M.Sc. in Aerospace Engineering from the University of Dayton in Dayton, Ohio and her Ph.D. in Mechanical Engineering from the University of London's Imperial College at London, United Kingdom. She is also a Distinguished Graduate of National Defense University's Industrial College of the Armed Forces, where she earned a M.Sc. in National Resource Strategy. Lourdes has served as a Lead Author for the Nobel-Prize winning United Nation's Intergovernmental Panel on Climate Change and the National Academies of Science National Research Council. She is an Associate Editor for American Institute of Aeronautics and Astronautics' (AIAA) *Journal of Propulsion and Power* and serves on the Editorial Board of the *International Journal of Aeroacoustics.* She has authored over 100 publications and is a 2003 Fellow of AIAA. Lourdes is a native of Havana, Cuba and grew up in Madrid, Spain and Dayton, Ohio. She became a U.S. citizen at 16. She is married to Dr. Mark S. Maurice and has one son, Anthony.

Chairwoman GIFFORDS. Thank you. Dr. Epstein.

STATEMENT OF DR. ALAN H. EPSTEIN, VICE PRESIDENT, TECHNOLOGY AND ENVIRONMENT, PRATT & WHITNEY, UNITED TECHNOLOGIES CORPORATION

Dr. EPSTEIN. Madam Chairwoman and Members of the Subcommittee, thank you for inviting me. Fifty years ago this January a Boeing 707 powered by Pratt & Whitney engines, flew the first transcontinental commercial jet flight in the United States. Since then, our jet engines have improved dramatically to the point where the most modern pure power engines consume only about half as much fuel as those on a 707. However, no progress has been made on civilian fuels. We use the same fuel today as we did in 1959.

First, let me address why biojet fuel is important to aviation. We expect commercial aviation to grow at an annual rate of four to five percent averaged over the next 40 years. Given a renewal of the public/private partnership in aeronautical research, engine and aircraft designers continue the two to two and a half percent per year improvement in fuel economy we have demonstrated over the last 50 years. However, without further action, aviation CO_2 would still grow two to three percent per year. The only solution is to move to a low-carbon fuel such as a sustainable biojet.

Simply put, biojet converts aircraft to solar power with the fuel simply serving as a chemical battery recharged by the sun. The many practical considerations of capital, manufacturing, logistics, combined with the imperative for near-term action on climate change means that a new fuel should be a drop-in fuel. Drop-in means a fuel that can be distributed and used without modification to delivery channels, aircraft or engines, and my comments are offered in the context of drop-in sustainable biofuels.

At Pratt & Whitney, we have been testing biofuels in the lab and engines. While lab testing is very useful, I cannot overemphasize the importance of full-scale tests. Pratt & Whitney has tested biojet blends in a variety of engine sizes ranging from those powering small business jets up to the Boeing 747. These tests revealed no negative effects on engine operation. Actually, pure biojet was better in that it reduced the particulates emissions important to local air quality.

This January, a Pratt & Whitney powered Japan Airlines Boeing 747 flew with a mix of conventional and second-generation biojet fuel. We saw no impact on performance or engine life. The test is noteworthy because of the varied feedstock used, camelina, jatropha and algae which shows that aviation need not bet on a single approach. We are planning an additional test flight next year. Each flight builds confidence.

Pratt & Whitney is also leading an international consortium looking at sustainable biofuels as applied to small gas turbines that power general aviation business and commuter aircraft. One thing we have learned is that an engine can be designed to reduce fuel consumption if we can be assured that all aircraft fuel was largely biojet. Unfortunately, no such gain can be had from current engines. While we do not expect these fuels to affect the economic life of the 70,000 Pratt & Whitney engines in the field, additional work, such as endurance testing, is a wise idea. Funding for such tests have yet to be identified.

The aviation community is sharing knowledge to certify biojet. This builds on our experience from the recent Air Force program which certified alternative fuels for energy independence.

So where do we go from here? Industry is working together to define appropriate standards, and I expect that biojet can be produced to meet these standards. So biojet can move into service with a few more tests, documentation, and action by the approving bodies which can be done in the next two to three years at which point all you need is commercial quantities of biojet.

So the challenges remaining are not in the realm of the propulsion engineer. They belong to the business community, to bio and chemical engineers, to ecologists, and to lawmakers.

The growth of the biojet market will depend upon cost and on capital. The cost of the fuel must reflect the value it brings to the purchaser, and capital is needed for biojet production facilities. This is where biojet research can help by reducing both the carbon and the capital needed to produce fuel.

Pratt & Whitney is bullish on biojet for aviation. Drop-in sustainable aviation biojet fuels are an excellent idea for the aviation industry, for the Nation and for the planet.

Thank you for permitting me to address this important topic.

[The prepared statement of Dr. Epstein follows:]

PREPARED STATEMENT OF ALAN H. EPSTEIN

Mr. Chairman and Members of the Subcommittee, I am Alan Epstein, Vice President of Technology and Environment at Pratt & Whitney, this country's foremost manufacturer of aircraft and rocket engines with over 70,000 engines in the field. Pratt & Whitney is part of United Technologies Corporation, a global technology corporation with a long history of pioneering innovation in aviation, space, climate control, elevators, and fuel cells. Because we power many of the world's airplanes and rockets, control climate in and move people around buildings in every corner of the globe, we are dedicated to reducing mankind's impact on climate change.

I am here to speak on sustainable aviation biojet fuels from the point of view of a manufacturer and maintainer of aircraft engines. I appreciate the opportunity to participate in this hearing which addresses one of the most promising avenues for aviation to reduce its impact on climate change.

This January was the 50th anniversary of the first commercial jet flight in the United States, a Boeing 707 powered by Pratt & Whitney engines. Since then, our jet engines have improved dramatically. The most modern engines, such as the new P&W PurePower Geared Turbo Fan engine family consumes only half as much fuel as those on the B707. However, no progress has been made on civil aviation fuels over these 50 years; today we still use the same fuel as we did in 1959.

Introduction to Biojet Fuels for Aviation

I am here to discuss how concerted action can move civil aviation toward new fuels; fuels which are benign to the environment and promote energy independence for the Nation. The reason why this is an important topic is that civil aviation is both a generator of national wealth and a reflection of it. Aerospace is this nation's largest manufacturing export and provides over half a million jobs in the U.S. We expect the world's commercial aviation to grow at an annual rate of four to five percent averaged over the next 40 years, reflecting an increase in global wealth. The CO_2 emissions from aviation are simply proportional to amount of fuel burned, so unless we take action, they will increase as well. We anticipate that a public-private partnership in aeronautical research can continue the two to two and a half percent per year improvement in fuel economy we have worked so hard to achieve over the last 50 years. Replacement of old airplanes with new, much more fuel efficient models is the mechanism by which this new technology reduces environmental impact. Of course, airlines need cash and credit to purchase new aircraft. Therefore, care must be taken that proposed economic measures such as carbon trading or taxes do not drain funds from aviation that are needed to renew airline fleets with fuel efficient, climate friendly new aircraft.

Even if all new aircraft and engines were introduced into the world's fleets, it would still result in a two to three percent average annual growth in aviation CO_2. To stem this CO_2 growth over the next 40 years the world must move to a new aviation fuel. It is important to note that all of the biofuels under consideration result in the same amount of CO_2 exiting a jet engine's tailpipe, an amount no different than that of today's petroleum based fuel. The difference important to the climate is the source of the carbon in the exhaust. In the case of petroleum, natural gas, and coal based fuels, this is fossil carbon, which was removed from the atmosphere eons before the advent of humankind. The large scale release of this fossil carbon is a major factor in the current climate change concerns. In the case of biofuels, the carbon has been recently extracted by plants and is then returned to the atmosphere by the engine. This extraction-addition cycle can be repeated indefinitely without disturbing our climate. The energy for the process comes, of course, from the sun. Thus in a very real sense, biojet fuels let us convert our aircraft to solar power. The biojet fuel simply serves as a chemical battery charged by the sun.

However, there is carbon release overhead in the process. Currently, fossil fuels are used in the cultivation, transport, and processing of the bio material. This is an area ripe for improvement and innovation, so I expect this carbon overhead will decrease dramatically as, for example, we learn to increase the efficiency of sustainable biojet fuel cultivation and processing. Even at its current state, biojet fuels add much less total carbon to the atmosphere than do petroleum based jet fuels.

There are many practical considerations of capital requirements, manufacturing capacity, and logistics, which when combined with the imperative for relatively near-term action on climate change mean that any new fuel should be a drop-in fuel. By drop-in we mean a fuel we can distribute and use without modification either to fuel distribution channels such as the pipelines and the tank farms or to airplanes and engines. For many of the same reasons, the biojet fuels must also be mixable with current jet fuels in arbitrary ratios. We now know that all these requirements are technically feasible. My following comments are offered in the context of drop-in biojet fuels.

With this as background, I will discuss what we have learned about biojet fuels for aviation and where we hope to go. Specifically I will touch on lessons learned in our research, ground, and flight testing.

What We Have Learned From Recent Flight Tests

While laboratory testing is very useful, since safety is our primary concern in aviation, I cannot overemphasize the importance of full scale ground and flight testing. Pratt & Whitney has tested biofuel blends in a variety of engine sizes ranging from those powering small business jets up to the Boeing 747. These tests revealed no negative effects on engine operations or their performance characteristics. Indeed, emissions measurements with pure biojet fuels showed that emissions of regulated particulates in the exhaust were reduced compared to those from conventional fuels. However, those gains were largely eliminated when we diluted biojet fuel with appreciable amounts of conventional fuel.

Preliminary results from the recent January 2009 flight tests on a Pratt & Whitney powered Japan Airlines Boeing 747 are that the mix of second generation biojet fuel and conventional fuel performed as expected, with no impact on performance and nothing of note observed in the post flight engine inspection. This result is another encouraging step toward approving biojet fuels for aviation applications. This flight test is particularly noteworthy because of the heterogeneous composition of the biojet fuel feedstock used—including camelina, jatropha, and algae. This shows that that biojet fuel can be processed properly from a variety of feedstocks; that such fuels can be mixed with each other and conventional fuel; and that aviation need not bet on a single source of fuel. Together this implies that biojet fuels can be a robust technical and commercial solution to aviation's CO_2 challenge.

Pratt & Whitney is working closely with the engine/airframe/equipment/fuel supplier community to harness the lessons learned in recent flight and ground tests of commercial aircraft and engines to establish the understanding and data base necessary to support the certification of biojet fuels for civil and military operations. We are sharing this information as needed under the auspices of DOD and the American Society of Testing and Materials (ASTM), which define the specifications for aviation fuels in this country. The community is benefiting greatly by the experience gained in recent years from the USAF sponsored efforts to certify alternative fuels made with the decades-old Fischer-Tropsch process. The primary motivation was DOD's desire for diversification of the U.S. energy supply to foster energy independence. Last year, Pratt and Whitney approved the use of these fuels in all non-after-burning P&W military engines (some of which are variants of commercial engines) and we expect to approve them for after-burning fighter aircraft by the end of this year. The climatic impact of these fuels can be significantly reduced if carbon sequestration or biomass is used in their production. Fischer-Tropsch fuels made with only biomass feedstock is one class of biojet fuel. The experience of certifying these fuels, the first all new fuel in decades, has taught the aviation community how to streamline the approval process such that it is now feasible to certify a biojet fuel within the next two to three years.

The next flight test demonstration with P&W involvement is the Jet Blue/Airbus/IAE (International Aero Engines)[1] flight test scheduled for next year using a blend of third generation biojet fuel feedstocks. To our knowledge this will be the first flight test using only third generation feedstock. In addition to generating data on an advanced type of biojet fuel, this demonstration will add value by broadening the experience base to include aircraft-engine types which have yet to fly with biojet fuels. This helps the industry to evaluate if there are less obvious or overlooked elements in the complex fuel systems of modern airplanes which might be affected. Also, the total flight time on biojet fuels is quite limited at the moment, so that each additional test flight helps to build confidence. Since safety is the predominate concern for aviation, the value of test data and flight experience cannot be underestimated.

Other activities

Pratt & Whitney is leading an international consortium which includes universities, government researchers, and biojet fuel suppliers looking at sustainable biofuels, specifically as applied to small gas turbine engines that power general aviation, business, and commuter aircraft.

One result of research at Pratt & Whitney is the realization that an advanced engine can be designed for improved performance if we could be assured that all aircraft fuel consisted in large measure of biojet fuel. By improved performance, we mean better fuel efficiency and lower engine weight. For example, the improved heat capacity of the biofuel lets us reduce or eliminate radiators and their attendant

[1] International Aero Engines (IAE) is a collaboration of Pratt & Whitney/Rolls-Royce/MTU/Japan Aerospace Corp which supplies the V2500 series of engines for Airbus A320 family aircraft.

weight and drag penalties. (The irony of increasingly efficient aircraft engines is that it becomes more difficult to reject waste heat.) There are two major constraints on realizing such improved performance. First, the engine must be expressly designed for biojet fuel or a biojet-conventional fuel mix. There is no performance gain from biofuels burned in current engines. Second, biofuel must be a substantial fraction of the fuel in the airplane, 25 percent or more. However, it may be several decades before biojet fuels are available in the tens of billions of gallons per year this implies, so that we are a ways off from being able to exploit some superior biofuel properties in our engine designs.

Our confidence as an industry in defining appropriate, formal standards for a drop-in biojet fuel is quite high and tests to date indicate that biofuels can be produced to meet appropriate standards. While we do not expect such fuels to affect engines' economic life, additional testing would be wise. Endurance tests are part of the normal development process for new engines and materials and would be recommended in this process. Also, once biojet fuels are deployed into commercial service, it would be prudent to institute in-service evaluations which periodically examine engines as they age. This is typically done when designs are changed or new materials are introduced. Funding for such tests and evaluations has yet to be identified.

It is important to note that the activities outlined above are not what we regard as research. The research required to introduce biofuels to civil aviation has been done, there are no unanswered scientific questions. What is required is a modest amount of straightforward engineering development. From the propulsion provider's point of view, all that is needed to move biojet fuel into civil service are a few more tests, documentation, and action by the approving bodies. Of course, you also need commercial quantities of certified, sustainable biojet fuel.

What Else Is Needed

Given concerted action, approval and certification of biojet fuels for civil aviation can be completed with the next two to three years. Then, biofuels meeting the approved specifications can be legally used in civil aviation. At that point, all you need is commercial quantities of biofuel. Therefore, the challenges remaining are not in the realm of the aeronautical or propulsion engineer. Once the aviation supplier community completes its approval of biojet fuel, the remaining questions and challenges belong to the business community, to bio and chemical engineers, to ecologists, and to lawmakers. The growth of the civil aviation biofuel market will depend on such factors as:

- The cost of the biojet fuel must reflect the value it brings to the purchaser, the airlines in the case of commercial aviation. In other words, biojet fuel must be cost competitive with petroleum based fuels, all things considered. Passing on increased airlines costs to consumers has not worked well in the past.
- Capital must be invested in the biojet fuel production chain. At the moment capital is in short supply, but we all hope that this is only a short-term challenge. The near-term formal certification of a biojet fuel standard should help to encourage investment.
- Authoritative, peer-reviewed quantitative research is needed to establish the carbon footprint of various biofuels and document their sustainable nature. This will be an ongoing process and should be supported by governments in independent organizations such as universities.

Innovation has been a mainstay of the long-term increase in U.S. productivity. Aviation biojet fuel is an area ripe for innovation, in technology and in business. We see significant opportunities for technical advancements in such areas as feedstock production to increase crop yields and decrease freshwater requirements in order to reduce cost and improve sustainability. Also, there is synergy with military fuel requirements and markets to foster U.S. energy independence.

All things considered, it is reasonable to anticipate that several percent of the world's civil aviation fuel may be supplied by biological sources by the end of the next decade.

Pratt & Whitney is bullish on biojet fuel for aviation. Simply put, drop-in, sustainable aviation biojet fuels are an excellent idea. They will reduce aviation's CO_2, while diversifying our fuel supply and promoting energy independence. Combined with continuing technical innovation in aircraft and engines, we see sustainable biojet fuels as enabling the growth in civil aviation that is critical to the Nation's and the world's economic growth.

Thank you for permitting me to address this important topic.

BIOGRAPHY FOR ALAN H. EPSTEIN

Alan Epstein is responsible for Pratt & Whitney's long-term technology and environmental strategy. Alan joined the company in August 2007, after a distinguished 30-year career with Massachusetts Institute of Technology (MIT), where he was R.C. Maclaurin Professor of Aeronautics and Astronautics, and Director of the Gas Turbine Laboratory.

Alan is leading Pratt & Whitney's efforts to identify and evaluate new methods to improve engine fuel efficiency and reduce noise and combustion emissions for all new Pratt & Whitney engines. Alan will also provide strategic leadership in the investment, development and incorporation of technologies that reduce the environmental impact of Pratt & Whitney products and services. In addition, Alan will also be responsible for validating Pratt & Whitney's technology and environmental strategy with customers, industry representatives and government agencies.

For more than 30 years, Alan has served on numerous government advisory committees and was an active consultant and advisor to industry and government on topics ranging from gas turbine engineering, power and energy, to strategic planning.

He was an author of the Intergovernmental Panel on Climate Change (IPCC) report on aviation and the environment, has been published in more than 120 technical publications, and has given more than 90 plenary, keynote and invited lectures around the world. He is a member of the U.S. National Academy of Engineering and a fellow of the American Institute of Aeronautics and Astronautics and of the American Society of Mechanical Engineers.

Alan received his Ph.D., M.S. and B.S. degrees from the Massachusetts Institute of Technology in Aeronautics and Astronautics.

Chairwoman GIFFORDS. Thank you. Mr. Glover.

STATEMENT OF MR. BILLY M. GLOVER, MANAGING DIRECTOR OF ENVIRONMENT STRATEGY, BOEING COMMERCIAL AIRPLANES

Mr. GLOVER. Good morning. Madam Chairwoman and Members of the Committee, thank you for this opportunity to testify. The Boeing Company designs and manufactures a range of commercial, military and space products. We are the largest aerospace company in the world, employing over 160,000 people, 155,000 here in the United States.

Today, Boeing produces a family of commercial aircraft, all quieter and more fuel efficient than earlier generations. We believe that sustainable biofuels for aviation have the potential for reduced life cycle greenhouse gas emissions and also the potential to increase fuel supply. Both important.

We have identified four plant-derived oils that have very strong potential: jatropha, camelina, halophytes and those things are available in the near-term, and algae in the longer-term. Aviation-quality biofuels derived from these sustainable energy crop sources show significant improvements when compared to traditional sources.

This is not your father's ethanol or biodiesel. It is chemically different. Overall, jatropha and camelina studies show greenhouse gas reductions 60 percent or more as compared to petroleum-derived jet fuel.

Let me make one thing abundantly clear. Boeing has no interest in becoming a biofuel producer. Our goal is to facilitate rapid commercialization of this new industry and capture this opportunity. We are very confident that sustainable sources of plant-derived oils and processing methods can efficiently produce a high-quality jet fuel. We have demonstrated that synthetic paraffinic kerosene made from plant oils can be blended up to 50 percent with normal jet fuel and operated in a commercial jetliner without modifications.

Over the last year, Boeing has conducted four successful flight demonstrations with Virgin Atlantic, Air New Zealand, Japan Airlines, and Continental Airlines. During each flight, a single engine was fueled by a blend of traditional Jet A and biofuels. The biofuels were produced by Imperium Renewables and Honeywell UOP.

While we have not completed all of our evaluations from these test flights, we found these new biofuels can actually perform better. They have a lower freeze point, better energy density, and no abnormal wear or engine deterioration.

Safety has always been and will continue to be the top priority of Boeing. The three biofuel blends used for the most recent flights and engine tests met all ASTM D 1655 performance specifications.

So what is the path forward? We believe the principal challenges are commercialization, growth and supply of viable feedstocks, and standard life cycle assessment. Our current projections are that with appropriate incentives, market viability could be achieved as early as 2015. Without such attention, market viability will be delayed.

As you know, aviation has few options to reduce greenhouse gas emissions. Other forms of transportation can use batteries and electrical power, for instance. We can't. Aviation must rely on three key strategies: continue to produce more efficient aircraft; number two, fly aircraft more efficiently by realizing the promise of NextGen and improved air traffic management systems; and finally, use sustainable biofuels.

Boeing urges governments to support commercialization and development of aviation biofuels by creating incentives for energy crop growers and producers of sustainable biofuels, by ensuring greenhouse gas legislation encourages the development of sustainable biofuels for aviation, by creating predictable demand incentives for aviation biofuel and assisting airlines to invest in these new supply chains, by implementing a refund of the aviation domestic fuel tax when biofuel blends are used, and finally by funding rapid development of standard methods for measuring life cycle carbon emissions and sustainability. It is foundational.

Boeing is fully committed to working with fuel producers, engine manufacturers, airlines, and government to ensure the earliest development of commercially viable markets for sustainable aviation biofuels. Thank you again for this opportunity.

[The prepared statement of Mr. Glover follows:]

PREPARED STATEMENT OF BILLY M. GLOVER

Madam Chairwoman and Members of the Committee, thank you for the opportunity to offer The Boeing Company's views on sustainable biofuels for aviation.

As many of you know, The Boeing Company ("Boeing") designs and manufactures a range of commercial, military and space products. We are the largest aerospace company in the world, employing over 160,000 people.

Today The Boeing Company produces a family of 18 different commercial aircraft—all quieter and more fuel efficient than earlier generations of aircraft. In fact, today's jet aircraft are 70 percent more fuel-efficient than jet aircraft produced only 50 years ago.

Despite the current global economic downturn, the demand for newer, more fuel efficient aircraft remains strong. In fact, we have almost 900 orders for our newest product, the 787 Dreamliner which should generate approximately a 20 percent reduction in fuel usage and emissions. We recognize, however, the aviation sector, as a key contributor to global GDP, must continually strive to improve its environmental performance to the extent possible and in line with industry growth. To be effective we must continue to make improvements on a global basis.[1]

Over the next 20 years, Boeing forecasts a demand for over 29,000 new large commercial aircraft worth approximately $3.2 trillion. We are concerned that demand for air travel and thus for commercial airplanes could be affected by future limits on CO_2 emissions. We therefore are committed to looking for environmentally-friendly solutions and alternatives to the way air travel is conducted today.

We believe that sustainable biofuels for aviation have the potential to provide greatly reduced life cycle greenhouse gas ("GHG") emissions and greater economic benefits associated with increased fuel availability.

When we use the term "sustainable biofuel" we mean a biofuel that, at a minimum, meets the following criteria:

1. Utilization of plants that do not compete with food, do not significantly impact biodiversity and do not jeopardize supplies of drinking water;
2. Total GHG emissions from plant growth, harvesting, processing and end-use are significantly lower than GHG emissions from fossil fuel extraction, production and end-use;
3. In developing economies, development projects include provisions or outcomes that improve socioeconomic conditions for small-scale farmers who rely on agriculture to feed their families, and do not require the involuntary displacement of local populations; and
4. High conservation value areas and native eco-systems are not cleared for aviation plant source development.

We have identified four plant-derived oils that have very strong potential to meet our sustainability criteria: jatropha, camelina and halophytes in the near-term, and algae in the longer-term. Biofuels derived from these sustainable energy crop sources show significant improvements in terms of yield and environmental impacts when compared to traditional food crop sources currently being used to make ethanol and biodiesel fuels.[2] Overall, jatropha and camelina studies show GHG reductions of 60 percent or more, as compared to petroleum-derived jet fuel.

It should be made abundantly clear that Boeing has no interest in becoming a biofuel producer. Instead, we are using our expertise and reputation as an innovator to draw attention to the opportunities for a clean, renewable fuel source in hopes of spurring and accelerating commercial development. In addition, we are using our technical capabilities to assure any new aviation biofuel meets all safety and performance requirements for our airplanes.

We are very confident that sustainable sources of plant-derived oils and processing methods can efficiently produce a high quality jet fuel. We have demonstrated that synthetic paraffinic kerosene ("SPK") made from plant oils can be blended up to 50 percent with normal jet fuel (Jet A or A–1) and operated in a commercial jetliner without any modification to the aircraft or engine.

When Boeing was asked to testify at this hearing, the Subcommittee posed a number of questions they would like us to address. Let me now turn to the Committee's questions.

Flight Demonstrations

Over the last year, Boeing has conducted four successful flight demonstrations with blends of biofuels. During each flight, a single engine was fueled by a mix of traditional Jet-A and biofuels.

- Virgin Atlantic Airways conducted the first test of a Boeing 747–400 with General Electric engines on February 25, 2008. That test flight operated be-

[1] Boeing is an active participant in the International Civil Aviation Organization (ICAO), the UN body that governs all aspects of international aviation. Through the ICAO Committee on Aviation Environmental Protection (CAEP) the industry has driven down aircraft specific emissions—CO_2, soot, and NO_Xx—on a global basis.

[2] Preliminary well-to-wake life cycle assessments were carried out by Michigan Technological University for jatropha and camelina oil based SPK (see Appendix). A similar algal oil study is currently underway.

The basis for these studies is from recently available data on crop yields, oil content, and cultivation requirements1. Both camelina and jatropha show great promise for increased energy oil productivity without negatively impacting land and water use. The results of these studies indicate that more than 60–65 percent reduction in GHG emissions can be achieved by hydrotreated jet fuel relative to petroleum-derived jet fuel.

tween London Heathrow and Amsterdam with an 80120 mixture of biofuel to kerosene.

- An Air New Zealand 747–400 equipped with Rolls-Royce engines was used to test a 50 percent biofuel blend in an engine ground run, and a test flight from Auckland, NZ on December 30, 2008. The flight lasted approximately two hours and consisted of climb, engine windmill restarts, as well as using starter-assists. Acceleration and deceleration checks were also carried out. A simulated approach-and-go-around was conducted at 10,000 ft.
- A Continental 737–800 with CFM engines was used to test a 50 percent jatropha and algae biofuel blend in an engine ground run, and an experimental flight from Houston, TX on Jan 7, 2009. The flight lasted approximately two hours, and consisted of a climb, engine accelerations and decelerations, a windmill engine restart, a starter assisted restart, and a simulated go-around maneuver at 10,000 ft.
- A JAL 747–300 with Pratt & Whitney engines was used to test a 50 percent biofuel blend in a ground run, and subsequent flight in Tokyo, Japan on Jan 30, 2009. The flight lasted approximately two hours, and consisted of a climb, engine accelerations and decelerations, and an engine windmill restart.

While we have not completed our evaluations from these test flights, some of the key lessons learned include the following:

- Lower freeze point—In an initial comparison of biomass-based jet fuel and jet fuel from petroleum, we saw better freeze point performance from the biofuel blend. This is extremely important because aviation fuels must be able to perform in the very low temperatures experienced at high altitudes.
- Better energy density—In several instances we observed better energy density in the fuel properties of the individual biofuels and in the biofuel blends when compared to traditional jet fuel. Higher energy density is an important benefit to aviation due to the unique lift needed to carry fuel for flight.
- No abnormal wear or engine deterioration—Post-flight inspections of the aircraft and engines were conducted prior to the aircraft returning to service or entering into regularly scheduled maintenance. No abnormal wear or engine deterioration was observed.

We have no announced plans for additional flight demonstrations at this time. Our efforts are now focused on commercialization and certification of these fuels for aviation use.

Research, Development and Testing of Biofuels

Safety has always been, and will continue to be, the top priority of the Boeing Company. Safety is at the forefront of our efforts to develop and certify sustainable biofuels. Our most fundamental requirement for sustainable biofuels for aviation is also the most important requirement for their safest use—sustainable biofuel must meet "drop-in" requirements—i.e., they must be able to be used in existing fuel delivery and supply systems and in existing aircraft without modification or special handling. And they must be fully compatible to be mixed with other approved fuels.

As discussed earlier, Boeing is developing a comprehensive report on the data collected from the recent flight and ground tests. We will be providing this report to the ASTM membership for further review and analysis. We are continuing to work closely with the ASTM[3] and other standards bodies in determining what additional research and/or testing may be necessary following completion of analysis and review of the results.[4]

The three sustainable biofuels used for the flight and engine tests met all ASTM D 1655 performance specifications at a 50 percent blend with petroleum-based jet fuel.

Fuel property tests took place at several locations including Boeing, Honeywell UOP, Air Force Research Lab, several independent outside laboratories and the participating engine companies. Additional property and performance tests, including material compatibility, were conducted on these fuels at Boeing labs, the Air Force

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[3] The ASTM requirements in development will ensure that bio-derived fuels meet strict performance and compositional specifications to be compatible with existing petroleum-based fuels.

[4] The ASTM process for specification of commercial aviation fuels supports the operational approval as administered by the FAA. It is a well established process. As a member of ASTM, Boeing is working closely with that body to establish a robust standard of certification for bio-derived fuels.

Research Labs and the University of Dayton Research Institute. Engine tests occurred at General Electric as well as Pratt & Whitney facilities.

Engine tests consisted of control, operability (engine start, flame-out and transient thrust characteristics) and performance, all of which tested within expected variation. No engine degradation was evident via control, operability and performance or hardware inspection at the conclusion of the test.

Operability testing included measuring start times, lean-blow out margin, acceleration and deceleration times. Emissions testing consisted of tests for the currently regulated emissions species; nitrogen oxides (NO_X), carbon monoxide (CO), hydrocarbons (HC), and smoke number.

Our testing revealed some surprising results, for example:

- The process to make the bio-derived SPK is feedstock agnostic;
- At a 50 percent blend ratio, a bio-derived SPK fuel performed equal to, and in some cases better than, traditional petroleum-based jet fuel in terms of performance and emissions;
- No change in aircraft systems, fueling infrastructure or engines is required for implementing bio-derived SPK fuels at up to a 50 percent ratio; and
- Large-scale production of a bio-derived SPK jet fuel is possible from sustainable sources.

The Path Forward

We believe the principal challenges facing widespread use of biofuels in aviation are in the areas of commercialization, growth and supply of viable feedstocks, establishing standard life cycle carbon and sustainability assessment methodologies and policies.

Right now biofuels, whether for aviation or other forms of transportation, are not being produced in sufficient quantities. This is due largely to the typical early challenges of commercializing an emerging technology, when development costs are highest and production processes have not yet reached economies of scale.

In addition, public policy investments and incentives often afforded existing technologies make it difficult for emerging technologies to be produced at competitive costs and offered at competitive prices. This is especially the case for emerging biofuels that must compete with decades of public and private infrastructure investments and extensive public policy incentives for fossil fuels. As a result, the sustained price of a barrel of oil needs to be at least $70 for biofuel producers to demonstrate competitive business cases that will generate the necessary investments in infrastructure (bio-refineries, equipment, etc.) and generate fuels that can be sold at prices competitive with existing fossil fuels.

Our current projections are that, with appropriate incentives, market viability could be achieved as early as 2015. Without such incentives, market viability will likely be delayed much later, possibly even a decade.

Boeing is convinced sustainable biofuels can significantly reduce aviation's carbon footprint. We are focusing our efforts on accelerating viable commercial markets for advanced biofuels from plant sources that do not compete with food crops and require minimal land and water use. We are committed to ensuring that our research and development investments in environmental improvements deliver significant greenhouse gas reductions.

While other forms of transportation have options to reduce their carbon footprint, for example by utilizing batteries and electric motors for propulsion systems, aviation must rely on three key strategies: continue to produce more fuel efficient aircraft; fly aircraft more efficiently by realizing the promise of NextGen and improved air traffic management systems; and use low carbon sustainable biofuels.

Government can support the earliest commercialization and development of sustainable biofuels for aviation by:

- Creating incentives for sustainable energy crop growers and producers of sustainable biofuels for aviation;
- Ensuring public policy addressing greenhouse gas emissions does not discourage the development and production of sustainable biofuels for aviation;
- Creating predictable demand incentives for aviation use of sustainable biofuel blends, and assisting airlines to invest in new fuel supply chains;
- Implementing a refund of the aviation domestic fuel tax when sustainable biofuel blends are used; and
- Funding rapid development and implementation of reasonable, pragmatic, and standard methodologies for measuring total life cycle carbon emissions and determining the sustainability of all liquid fuels.

Boeing is fully committed to working with fuel producers, airlines and the government to ensure the earliest development of commercially viable markets for low carbon sustainable biofuels for current and future aircraft generations.

Thank you again for the opportunity to testify today.

Appendix

Life Cycle Assessment of Green Jet From Plant Oils and Tallow: *Comparison to Petroleum Jet Fuel;* February 2, 2009; Dr. David Shonnard, Ph.D. - Professor and Robbins Chair in Sustainable Use of Materials, Kenneth Koers, M.S.- Department of Chemical Engineering and Sustainable Futures Institute; Michigan Technological University; Houghton, MI, USA; Copyright © David R. Shonnard, Kenneth P. Koers, Michigan Technological University, and UOP LLC

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4.3 GREENHOUSE GAS EMISSIONS

The emission of greenhouse gases (GHG) over the life cycle for each jet fuel alternative is shown in Figures 4 and 5. The GHG emissions include CO_2, CH_4, N_2O, and a large number of refrigerants and solvents having large global warming potentials. Only the first three gases make a large enough contribution to this analysis to be included in the figures. Figure 4 shows that only petroleum jet contributes GHG emissions during aircraft operation, and this portion to the petroleum jet GHG profile is the largest. About 15% of petroleum jet's GHG emissions occur during other stages of the life cyclce; prominently crude oil production and refining for fuel production. Biofuels such as green jet contain no fossil carbons in the fuel molecules, only carbon atoms sequestered from the atmosphere as CO_2 during plant growth. Therefore, these fuels do not contribute to climate warming when combustion occurs. The largest contribution to green jet GHG emissions occurs for plant cultivation for camelina and jatropha, followed by fuel production, plant oil production, and transportation. The largest contribution to the GHG profile for tallow GJ is from fuel production, since no impacts were included for tallow collection in this study. The GHG emissions for Camelina GJ show nearly a 62% savings compared to petroleum jet, and the GHG savings for jatropha GJ are nearly 65%, while for tallow GJ, savings are just over 90%.

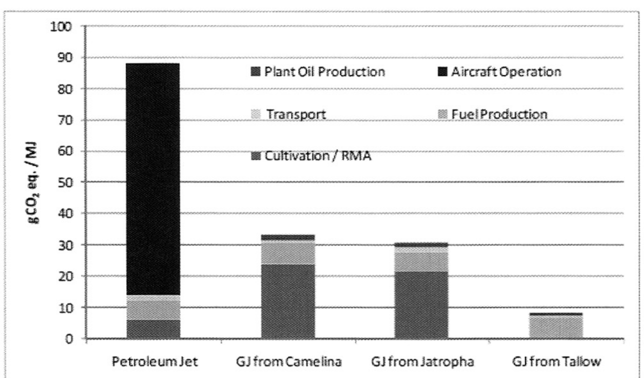


Figure 4: Greenhouse gas emissions for all fuels considered in this study

Chairwoman GIFFORDS. Thank you, Mr. Glover. Mr. Shannon.

STATEMENT OF MR. HOLDEN E. SHANNON, SENIOR VICE PRESIDENT, GLOBAL REAL ESTATE AND SECURITY, CONTINENTAL AIRLINES

Mr. SHANNON. Good morning. My name is Holden Shannon, and I am Senior Vice President of Global Real Estate and Security which includes environmental affairs for Continental. Continental has a long-standing commitment to providing customers clean, safe, and reliable air service while maintaining a commitment to the environment. Continental is the world's fifth largest airline, serving 131 domestic destinations, 134 international destinations on four hubs, Houston, Cleveland, Newark, and Guam in the South Pacific, and along with Continental Express, we are able to carry our 69 million passengers far more efficiently now than we were a decade ago.

In fact, since 1997, we have reduced the fuel consumption and emissions required to transport a mainline passenger one mile by 35 percent, which has been largely due to our friends at Boeing, a $12 billion investment in new aircraft, and a whole host of electrification efforts on the ground in Houston, Newark, among other things.

Today's airplanes are in fact technologically advanced. They are quieter, cleaner, and very importantly burn less fuel. That is why our industry represents just two percent of all greenhouse gas emissions in the United States despite continuous growth.

To give you some perspective, today Continental uses approximately 18 gallons of fuel to carry a passenger 1,000 miles, about the distance from Houston to Chicago. That same passenger would burn 45 gallons driving. It is a pretty significant difference.

Between 1978 and 2007, say 30 years, the airline industry as a whole has improved fuel efficiency a whopping 110 percent resulting in 2.5 billion metric tonnes of greenhouse gases. To put it in layman's terms, that is approximately the equivalent of taking 19 million cars off the road each year.

Airlines in fact have a strong economic incentive to reduce fuel consumption and resulting greenhouse gas emissions. Fuel, as Congressman Olson pointed out, has been a very unpredictable part of our cost. It is the most volatile aspect of our cost structure in an industry that really does have historically low returns, razor-thin margins. Fuel costs last year, and admittedly fuel goes up and down, but as a whole, it represents 30 percent to 40 percent of our cost, greater than any of our employee costs, wages, benefits, pensions, any of our airplane costs, and any of our facilities worldwide, so by far, the largest cost.

Unlike other sectors of the economy, airlines have no alternative but to consume jet fuel as one of my colleagues pointed out, but that could change. Because of our dependence on current fuel sources, as well as our commitment to the environment and our interest in using alternative energy, we decided over a year ago to partner with Boeing and GE Aviation among others to conduct a biofuels flight demonstration in Houston to help identify sustainable biofuel solutions for our industry.

In our case, we used an algae and jatropha biofuel blend, and this in fact was a second-generation biofuel that produces more energy than earlier biofuels and does not compete with foodstocks. That is a very important point. As a result, we believe it will be more stable and commercially viable as a fuel source than first generation fuels such as ethanol which one of my colleagues referenced as well, the basic problem with ethanol being that it just doesn't have enough kick to be carried relative to the weight that we would need it to generate on an aircraft.

The biofuel demonstration last January I believe was a huge success, and although as Mr. Glover has pointed out, we aren't completely finished with the results. We think that the results will be very, very positive. Our analysis of the digital flight data recorder and other data found on the aircraft showed us that it performed the same way that traditional jet fuel did except that during the life cycle, of course, when you are growing plants, we think we could achieve carbon neutrality.

The test itself was highly successful, but much remains to be done to meet widespread use. With the help of government and continued coordination of users, manufacturers, fuel suppliers, we believe that as long as an alternative fuel is certified for aircraft use, meets the drop-in fuel requirement as Dr. Epstein explained, meaning that no engine modifications are necessary for it to be added at any ratio with traditional fuel sources, and can be made available at an economically competitive price, is not a small matter, particularly in the case of algae which of course is still at its embryonic stages of development, aircraft operators will have the confidence to start using biofuel in the next five to ten years.

Continuing this process is a priority. Even though there has been a downturn in fuel prices, fuel efficiency remains a very huge concern for us and for our industry as well as for our nation. Further reducing carbon emissions and increasing fuel efficiency of course is something that all of us embrace.

While there is still today considerable price difference between traditional jet fuel and plant fuels, we have great confidence that that spread will lessen as supplies of plant fuel become more plentiful. The fact that plant fuel can be mixed in with traditional fuel and can be dropped right into older engines again means acceptance of the biofuel sources will grow in line with supply.

Biofuels represent an important tool for the airline industry to reduce their already-small greenhouse gas footprint of two to three percent worldwide. We would be remiss if we did not mention that more focus on the potential, the development, and the use of alternative fuels, as well as other available options which all of us have talked about such as the proposed NextGen efforts to modernize air traffic control system, which by itself would reduce fuel burned by 12 percent for our industry, a huge number, that they are collectively far more commercially productive than to consider imposition of some kind of cap-and-trade policy on the airlines which would further depress an already-beleaguered but necessary industry of air transportation as well as the economy.

As you probably know, government actions which cap a company's existing carbon footprint can be unfair and certainly don't reward innovative companies like Continental Airlines. At a time when our nation and Congress are focused on financial stability, we ask you to consider that.

Again, thank you for the opportunity to testify at this hearing. We very much appreciate your interest in this subject matter. We look forward to working with you, and we are available for questions.

[The prepared statement of Mr. Shannon follows:]

PREPARED STATEMENT OF HOLDEN E. SHANNON

INTRODUCTION AND OVERVIEW

Good Morning. Thank you for inviting me here to testify. My name is Holden Shannon and I am the Senior Vice President of Global Real Estate and Security for Continental Airlines. I am responsible for all real estate, security and environmental affairs throughout Continental's worldwide network. For starters today, I would like to point out that we have a long-standing commitment to environmental responsibility and providing our customers clean, safe, and reliable air service. Continental is the world's fifth largest airline operating *2,500* daily flights to *134* domestic destinations and 131 international destinations through hubs at Newark, Cleveland, Houston, and Guam, and together with Continental Express, we are able to carry our annual 69 million passengers far more efficiently than we did a decade ago.

In fact, since 1997, we have reduced the fuel consumption and emissions required to transport a mainline passenger one mile by 35 percent, largely due to our $12 billion investment in new fuel-efficient Boeing aircraft and related equipment. Today's airplanes are not just technologically advanced—they are quieter, cleaner and use less fuel than ever before.

That is why our industry represents just two percent of all greenhouse gas emissions in the United States. To give you some perspective, today Continental uses about 18 gallons of jet fuel to fly one revenue passenger 1,000 miles—about the distance between Houston and Chicago. By contrast, that same passenger driving his or her car between Houston and Chicago today would burn about 45 gallons of gasoline.

In fact, between 1978 and 2007 the airline industry as a whole improved its fuel efficiency, as measured by revenue ton miles per gallon of fuel, by 110 percent, resulting in 2.5 billion metric tons of greenhouse gas (GHG) savings—roughly equivalent to taking more that 18.7 million cars off the road in each of those years! And data from the Bureau of Transportation Statistics confirms that U.S. airlines burned almost three percent less fuel in 2007 than they did in 2000, resulting in absolute reductions in emissions, even though they carried 20 percent more passengers and cargo. Recent data suggests further gains in fuel and GHG efficiencies in 2008.

It is an often overlooked fact that airlines have a strong economic incentive to reduce fuel consumption and the resulting GHG emissions because fuel accounts for a significant—and volatile part of our operating budget. In fact, last year, fuel cost Continental more than all of its wages, salaries and benefits worldwide, and more than all of its airplanes worldwide, and more than all of its hubs and other facilities worldwide. And, unlike other sectors of the economy, airlines have no alternative but to consume jet fuel. Fortunately, with the industry's support, commercial aircraft and engine manufacturers have succeeded in creating significantly more aerodynamic planes and significantly more fuel efficient engines than those of prior generations, resulting in the tremendous decrease in GHG savings I have already described.

Continental, because it has invested $12 billion in new Boeing aircraft and other related equipment, has one of the youngest and most environmentally friendly fleets in the world. While this investment has already reduced our CO_2 emissions significantly, we are not stopping there. We have plans to invest over $11 billion more in new Boeing aircraft over the next six years so we will further improve our fuel efficiency and reduce emissions. And, as other U.S. airlines also invest billions of dollars in new, more energy efficient aircraft, we will continue to see additional significant environmental benefits industry wide.

However, any further major advances in **aircraft** fuel efficiency will be dependent on new engine and airframe technologies that are not yet available in the market place and are not likely to be a significant factor for much of the fleet for the intermediate-term.

Therefore, any **achievable** short- to medium-term environmental gains depend on two factors. The first factor is that the government must make a significant investment in the decades-old and out of date government-run Air Traffic Control system which, if modernized, is projected to reduce greenhouse emissions from aircraft by 12 percent by 2025. This action would be roughly equivalent to taking another 2.2 million cars off the road each year.

The second factor is that we need to stabilize energy supplies at stable prices which include safe and commercially viable alternatives to crude-oil based fuels.

While we are here today to discuss this second goal, I am attaching, for the record, the testimony of James May, CEO of the Air Transport Association, who just last week testified before the House Aviation Subcommittee on the near-term achievable goals for NextGen, which is the modernized ATC system. For the record, we would like to thank this subcommittee and the Full Science and Technology Committee for their steady record of cooperation with the House Transportation and Infrastructure Committee in focusing on the development and funding of NextGen as discussed in last session's FAA Reauthorization Bill as well as H.R. 915, this year's FAA Reauthorization bill. We appreciate the fact that you all understand the role that NextGen can play in reducing GHG.

THE CO BIOFUELS TEST: RESULTS AND CHALLENGES AHEAD

As regard to alternative fuels, because of our commitment to the environment and our leadership in this arena, we decided over a year ago to partner with The Boeing Company and GE Aviation/CFM International to conduct a biofuels flight demonstration to help identify sustainable biofuel solutions for the aviation industry. Together, we wanted to help continue the evolution toward fuel sources that absorb carbon before the fuel source is consumed, offsetting carbon that is emitted when the fuel is burned.

As a result, Continental performed the first sustainable biofuel flight demonstration in North America on January 7th, 2009, using a two-engine Boeing 737–800 aircraft. That demonstration flight represented many industry firsts:

- The first commercial carrier biofuel flight in NORTH AMERICA
- The first commercial carrier biofuel flight using biofuel derived from ALGAE
- The first commercial carrier biofuel flight using a TWO-ENGINE AIRCRAFT

We worked closely with our partners at Boeing, GE Aviation/CFM International, Honeywell's UOP, and fuel providers Sapphire Energy and Terasol Energy to make the flight demonstration a success. Continental's primary role in the demonstration was to show that the biofuel blend would perform just like traditional jet fuel in our existing aircraft without modification of the engines or the aircraft. We call a fuel like this a "drop-in" fuel. This is important because, as I mentioned, the current engine and airframe technology is unlikely to change materially for many years, so it is crucial that alternative fuel be safe for use with the current aircraft technology.

Although the flight demonstration was one small step of many toward the development of alternative energy solutions, we were able to help gather important data that is needed for the fuel certification process before the biofuel can be used by the airline industry.

The algae and jatropha biofuel blend used in our demonstration flight is considered a second-generation fuel and represents a significant advancement over first-generation fuels like ethanol. Second generation feedstocks like algae and jatropha produce more energy per hectare than traditional, first-generation biofuels and, as a result will be more stable and commercially viable. Moreover, they do not compete with foodstocks, as for example corn-based ethanol does.

To this end, Continental was pleased that the fuel property and performance tests showed that the biofuel blend we tested acted just like traditional jet fuel. The multitude of tests performed by Boeing, CFM, UOP, the Air Force Research Lab, as well as other third party labs on the biofuel prior to our flight, all show that the biofuel we used performs just like traditional jet fuel, with no difference in engine or system performance. Continental is working with Boeing and all of its other flight test partners to compile the results of the testing performed on the various biofuels used in other carriers' flight demonstrations. The results will be shared with the industry and used to help certify alternative fuel for use by the aviation industry.

After we performed our biofuel demonstration flight, we analyzed the digital flight data recorder and other data from the flight to measure the engine performance. We found that the engine and aircraft successfully performed just as they would have using traditional jet fuel, so the test aircraft was returned to revenue service the next day. We do not anticipate any long-term negative impact on aircraft from biofuel use as long as it meets the American Society for Testing and Materials

(ASTM) fuel certification standard and "drop-in" fuel criteria. Preliminary tests do show that the biofuels exhibit less smoke, so there may be some benefits that will require closer study, but we are not aware of a need to perform any additional demonstrations.

While we were pleased with the test results we have obtained to date, we would like to see additional long-term materials compatibility testing for system components like o-rings and seals by the manufacturers and the wide dissemination of these results. The U.S. organization that certifies jet fuel specifications for use in commercial aircraft is the American Society for Testing and Materials (ASTM) International. They will engage in an extensive data review process before approving new fuel specifications and will decide whether any additional demonstrations are necessary.

While the test itself was highly successful, significant challenges must still be overcome to meet our goal of widespread use of biofuels in aviation.

- A fuel specific standard must be developed which meets key performance and compatibility criteria to ensure safety.
- We will also need to develop a U.S. regulatory requirement mandating the level of quality throughout the supply chain; starting at the refinery all the way through to the airport.
- Federal support will be needed to accelerate the approval and deployment of several alternative aviation fuels that have already been developed and tested.
- Increased funding will be needed for ongoing U.S. military efforts to develop alternative fuels for military jet fleets that will transition to commercial fleets.
- Because of the economic slowdown, investment dollars for already conceived pilot plants and full-scale production plants has dried up. Direct federal support for such infrastructure investments and greater support in the area of research and development, including the feasibility of pipeline use for biofuel transport, may be needed to allow the development plans to proceed.
- In the end, we not only need a stable supply of energy which is independent from foreign oil, but any alternative fuel sources need to be produced in large enough volumes that they are available at an economically viable price. It will take many years to make a robust supply of alternative fuels and a network to deliver it to airports, so continuing our work toward that goal is important now.

With the help of the government and continued coordination of the industry, manufacturers and fuel suppliers, we believe that, as long as an alternative fuel is certified for aircraft use, meets the "drop-in" fuel requirement and is available at an economically competitive price as compared to traditional jet fuel, aircraft operators will have the confidence to start using biofuel blends in revenue flights in the next five to ten years. As the supplies increase in a commercially viable way, we will be able to increase the blend percentage over the years. Continuing this process is a priority, even though there has been a downturn in fuel prices. Fuel efficiency remains an important concern for us and for our nation, and further reducing carbon emissions and increasing fuel efficiency remains our goal.

CONCLUSION

One final message for today—as an airline which has invested billions and taken a leadership role in the efforts to increase fuel efficiency, we do want to raise our concerns over certain global climate change proposals which could act to disincentivize companies like Continental who have been proactive in their efforts to reduce their carbon footprint without government mandates.

Any government action that has the effect of capping a company at its existing carbon footprint and then "rewarding" any improvement from that cap punishes companies like Continental, who have been doing the right thing for years by reducing our greenhouse gas emissions.

Biofuels represents an important option for the airline industry to reduce their already small greenhouse gas footprint. And we know that this committee is well aware of the potential for the use of alternative fuels in the airline industry. We would be remiss if we did not mention that more focus on the potential, the development and the use of alternative fuels is far more productive than to consider the imposition of some kind of cap and trade policy on the airlines.

If it is our goal to encourage investments in infrastructure and innovations which improve the environment, leaders must be careful to support and nurture the efforts of companies like Continental who are leaders in those efforts.

We are confident that the measures that Continental, Boeing, and so many others are undertaking and supporting will continue to limit and even reduce aviation's emissions footprint. Commercial airlines can and will remain a very small source of greenhouse gas emissions while continuing to provide our communities, our states and our countries with a way to move people and goods around the globe. Job growth and the global marketplace are critically dependent upon a viable air transportation system and it is clear to us that more air transportation capacity will be necessary, not less.

Again, my thanks to the Science and Technology Committee for holding today's hearing and inviting our participation. We appreciate your leadership in these matters and look forward to working with you to integrate sustainable alternative fuels into the aviation industry in the future.

ATA TESTIMONY

Air Traffic Control Modernization and NextGen: Near-Term Achievable Goals

Statement of James C. May
President and CEO
Air Transport Association of America, Inc.
before the
Subcommittee on Aviation
of the
House Committee on Transportation and Infrastructure

March 18, 2009

AIR TRANSPORT ASSOCIATION

Introduction

The time to jump-start air traffic control (ATC) system modernization is now. A meaningful down payment over the next few years will pay dividends in the form of greatly improved system performance and corresponding public benefits.

The shortcomings of the existing ATC system are well known. Technologically, it is outdated and limited in its capabilities. It relies on ground-based radar for surveillance and navigation, and voice communications to relay instructions between controllers and pilots. Compared to modern and emerging technologies, our ATC system is slow and cumbersome. These limitations force operational procedures such as separation standards and indirect point-to-point routings that are inefficient because they appropriately put safety first. Consequently, as U.S. civil aviation has grown and become more complex – including scheduled commercial, nonscheduled business, public and private charter, air taxi and private recreational flying – the ATC system has become strained and, in some geographic areas, overwhelmed. This is especially true when severe winter or summer weather disrupts normal operations. The result is congestion and delay for all system users, unhappy passengers and shippers, and airlines who struggle to recover normal operations and rebook passengers when forced to cancel flights.

The current ATC system limitations impose significant costs on our society in general, and the airline industry in particular. The Joint Economic Committee estimates air travel delays impose $41 billion annually in costs on the U.S. economy.[1] In the 12-month period ending September 2008, 138 million system delay minutes drove an estimated $10 billion in direct operating costs for scheduled U.S. passenger airlines and cost airline passengers an estimated $4.5 billion in lost wages and productivity. These figures do not capture the costs of extra gates and ground personnel to passenger airlines or the direct costs incurred by cargo airlines and their customers. The airline industry cannot survive, and the public will not invest in it, if these conditions remain *status quo*.

Looking forward, these problems will only worsen unless and until change occurs. By 2025, the Federal Aviation Administration (FAA) forecasts there will be approximately 30,000 more operations per day than the 2007 estimate of 44,000 daily operations. The current ATC system cannot handle this projected future demand, even if the forecast is reduced to account for current economic conditions. Even if the forecasted growth is significantly reduced, today's ATC system is so inefficient that it will not be able to handle a modest increase in activity.

Why is this important?

The ATC system is a critical national infrastructure that serves the American people and the commerce of the United States, and all system users rely on it, especially the scheduled airline industry. The airline industry is the foundation of the commercial aviation sector, which comprises airlines, airports, manufacturers and associated vendors. **U.S. commercial aviation ultimately drives $1.1 trillion per year in U.S. economic activity and 10.2 million U.S. jobs.** By any measure, the U.S. airline industry is a valuable national asset and its continued economic health should be a matter of national concern. Without a modern, efficient ATC system, the airline industry will slowly strangle, U.S. commerce and productivity will be impaired and U.S. businesses will not be able to compete effectively in the global economy. For these reasons, modernizing the ATC system now is critically important to the growth and competitiveness of our economy.

ATC Modernization – NextGen – Will Provide Critically Needed Benefits

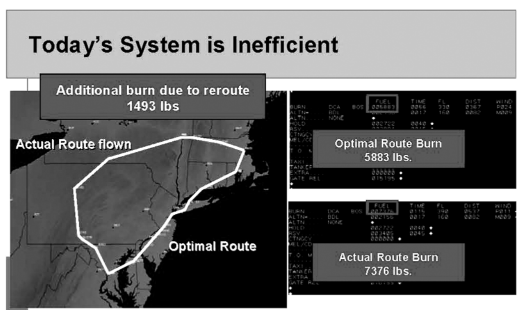
[1] http://jec.senate.gov/index.cfm?FuseAction=Reports.Reports&ContentRecord_id=11116dd7-973c-61e2-4874-a6a18790a81b&Region_id=&Issue_id=

The FAA ATC modernization project – the Next Generation Air Transportation System (NextGen) – will usher in a new era of air traffic management and control that promises enormous benefits for all stakeholders and the American people. Public benefits include improved operational efficiency, reduced fuel consumption and emissions and lower operating costs for airlines. ATA strongly supports NextGen because it addresses numerous critical needs:

- **Capacity.** The current ATC system is saturated and, in some locations, cannot provide the capacity to meet public demand for convenient, safe air transportation. This situation inhibits competition and industry growth. It also is the source of unnecessary congestion and delays, and compounds the effect of weather-related delays. NextGen will enable more precise spacing of aircraft and flight paths, which will allow FAA to handle safely and efficiently the traffic growth that it forecasts.

- **Efficiency and Productivity.** NextGen will enable more efficient flying. Today's ground-based radar system requires planes to fly over specific points on the ground to maintain radar and communications contact. Navigational aids, radar and controllers are all terrestrial. They are linked to form a complex network system that supports airways, through which aircraft fly. Today's system also requires spacing to accommodate the time it takes for radar to detect objects. Consequently, aircraft fly indirect routings and aircraft spacing – required for safety – wastes capacity. Today's ATC system cannot, and never will be able to, take full advantage of available technology or integrate and fully exploit emerging technology.

  The environmental and economic impact of today's inefficient ATC system is illustrated below. The flight in this example burned an additional 1,493 pounds of fuel (218 gallons). This added an extra 4,560 pounds of carbon dioxide (CO_2) that was released into the air and cost the carrier an extra $688 in fuel (given razor-thin margins, this is significant).



Large Air Carrier: DCA to BOS, December 2008

In contrast to today's ATC system, NextGen will enable: optimized, direct routings between airports; reduced aircraft spacing; continuous descent arrivals, precise arrival and departure routings (known as RNAV and RNP procedures), and closely spaced approaches on parallel runways in instrument flight rule conditions. These are just a few of the operational benefits of NextGen.

These efficiency enhancements will drive significant improvements in productivity – both in terms of asset utilization and personnel. That, in turn, will reduce operating costs, which will help keep fares down and enable those savings to be plowed back into wages and benefits and operating capital.

Improved ATC efficiency also will benefit private aircraft owners. Corporations use private aircraft with the expectation that such use is efficient. While we disagree with that proposition, ATC modernization will provide corporate aircraft owners the same kind of efficiency benefits that commercial airlines will enjoy if their aircraft are properly equipped. Even if they are not properly equipped, they still will enjoy a spinoff benefit simply from operating in the same airspace as more efficient commercial aircraft.

- **Environmental Benefits.** More efficient operations also will use less fuel, increasing aircraft fuel efficiency and reducing greenhouse gas and other emissions. It was estimated initially that full implementation of NextGen would reduce emissions significantly. The environmental benefits of ATC modernization are real and important. Improved fuel efficiency also will reduce operating costs and contribute to improved financial conditions that, like the productivity improvements discussed above, will benefit the public and employees.

- **Operational Integrity and Customer Satisfaction.** Closely linked to capacity, efficiency and productivity is operational integrity. By expanding capacity and enabling more efficient operations, NextGen will enable better on-time performance and improved customer satisfaction. Today's outdated ATC system contributes to delays and disruptions that could be avoided and will be avoided when NextGen is implemented. With improved operational integrity comes fewer delays, fewer missed connections, fewer misplaced checked bags and more satisfied customers.

- **Safety.** The NextGen satellite-based system will look and act much like a network to which aircraft and ATC are interconnected. It will provide more precise information to both controllers and pilots about aircraft locations, both in the air and on the ground, and will enable aircraft to constantly know one another's locations. This locational awareness and corresponding digital communications capability will provide critical real-time flight status information not available today. Some of the technology and operating procedures already have been tested and produced dramatic results. A sharp drop in aircraft accidents in Alaska occurred under the Capstone Program, introduced earlier this decade, which utilizes ADS-B technology, a foundational technology for NextGen.

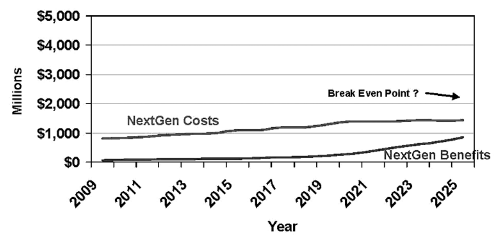
- **Scalability.** NextGen will be considerably more nimble than today's facility- and labor-intensive system. Accordingly, it will be much easier for the FAA to scale the system to meet demand from all aviation sectors, whether that demand is a steady growth curve or fluctuates from time to time. Automation and digital data communications will make it easier for the FAA to adjust the system as needed.

- **Improved Financial Performance.** Modernization will respond to legitimate shareholder expectations that the airlines they invest in will earn a positive return on investment. The current ATC system hobbles the industry's ability to achieve financial stability because of the costs it drives by being inefficient. As noted above, these failures lead to costly delays and congestion.

THE NEXTGEN PLAN FLAW – DELAYED BENEFITS

While we strongly support NextGen, the current FAA plan does not produce significant benefits – the capacity, efficiency and economic benefits described above – for the traveling and shipping public or for system users until 2025. For system users – airlines, business aviation and general aviation – this delay presents a special problem. The plan contemplates significant stakeholder investment, in addition to FAA investment, but no real benefit for many years. Without a timely return on investment, there is little incentive for airlines and other users to invest in new equipment and training. In short, the current FAA plan does not make a strong business case. Airlines, air taxis, charter operators and corporate aircraft owners have a fiduciary responsibility to their shareholders and owners to achieve a reasonable return on their investment in this context, just as they do with respect to any other major capital expense.

Current NextGen Cost/Benefit Projection



Note: Cost projection based on 2009 FAA NextGen budget proposal with 5% annual increase through 2025. Benefit projections based on ATA analysis of estimates by government and industry sources.

This flaw is particularly troublesome given the fragile state of the U.S. airline industry. 2008 saw U.S. airlines lose an estimated $8 billion (final, audited results are not yet available) on top of the $31 billion lost since 2000. Airlines reduced operations sharply and were forced to slash 28,000 jobs in 2008; additional reductions are already in place for 2009 and softening demand will require even further reductions as carriers continue to cut back operations. Should jet fuel prices move sharply upward, the industry could easily see 2009 losses approaching the magnitude of losses in 2008.

THE NEXTGEN SOLUTION: ACCELERATE READY CAPABILITIES TO DRIVE EARLY BENEFITS

The flaws in the NextGen plan can be overcome. There is a real and achievable solution, and that is to advance the point in time when the investment in NextGen begins to pay off for both the public and vested stakeholders. If the public and aviation stakeholders begin to realize the benefits in a few years instead of 10 or more, then the NextGen business case improves dramatically.

To accomplish this critical shift, the government must accelerate its near-term investment in NextGen, with a corresponding reduction in later years, in order to leverage existing technology in the near term. This investment will stimulate accelerated manufacture and installation of ground infrastructure facilities, required avionics, and development and certification of new operations procedures. This proposal includes only those elements that are proven and ready to deploy:

- Automatic Dependent Surveillance-Broadcast (ADS-B) – ADS-B is a critical component of NextGen. By relying upon satellite and additional technology, ADS-B enables an aircraft to constantly broadcast its current position simultaneously to air traffic controllers and other aircraft. Tremendous safety, security, capacity and environmental improvements are realized. Unlike ground radars, ADS-B offers much more precise data on an aircraft's position in the sky or on the runway, including altitude, category of aircraft, airspeed and identification. ADS-B has two components. ADS-B "Out" and "In". ADS-B "Out" continuously transmits an aircraft's position, altitude and intent to controllers. ADS-B "In" is the reception of the transmitted data by other aircraft, which allows pilots to have a complete picture of their aircraft in relation to other traffic, both in the air and on the ground. ADS-B has the potential to reduce delays, reduce fuel burn through more efficient routings, and increase capacity – all while improving safety.

- Area Navigation (RNAV) – enables aircraft to fly on any path within coverage of ground- or space-based navigation aids, permitting more access and flexibility for efficient point-to-point operations.

- Required Navigation Performance (RNP) – like RNAV, RNP enables aircraft to fly on any path within coverage of ground- or space-based navigation aids, but also includes an onboard performance monitoring capability; RNP enables closer en route spacing without intervention by air traffic control, and permits more precise and consistent departures/arrivals.

- Electronic Display Upgrades – will allow the display of traffic information that becomes available with ADS-B deployment and reduce the risk of runway incursions. Whether upgrades to existing forward displays or the addition of a supplemental display (such as an Electronic Flight Bag), users will be able to see other traffic while taxiing and have access to surface navigation tools, electronic versions of airport maps and pilot handbook materials.

- Ground-Based Augmentation System (GBAS) – GBAS is the next-generation technology to support precision landings. It provides additional information to aircraft to allow GPS to be used for landings in low-visibility conditions. This minimizes schedule disruptions due to weather, and also enables more environmentally friendly procedures and increased safety during ground operations.

- Localizer Performance with Vertical Guidance (LPV) – approaches leverage satellite-based precision to improve safety and provide all-weather access at thousands of general aviation airports, critical to the general aviation community.

In addition to accelerating the government's investment in NextGen, we also propose targeted deployment to those metropolitan areas and regions of the country where it is most needed to address congestion and delays, such as New York/Philadelphia, Chicago, Atlanta, San Francisco and Los Angeles. Deploying these capabilities in high-value locations before expanding to other areas will maximize NextGen benefits for the greatest number of people.

To support the earliest possible delivery of benefits and further investment by carriers, we also endorse the FAA "best equipped/best served" principle included in the governing principles of the NextGen 2009 Implementation Plan. Under this principle, consistent with safe and efficient operations, FAA will provide priority in the National Airspace System to Next-Gen equipped aircraft.

Accelerated and targeted deployment will produce significant benefits for the flying public in terms of airspace capacity and efficiency. It will lead to improved reliability and on-time performance, thereby greatly diminishing (if not eliminating) the single biggest source of the public's dissatisfaction with flying. It should also drive improvements in other customer service areas such as checked baggage delivery and long taxi-out times.

OTHER CHALLENGES ALSO MUST BE OVERCOME TO REALIZE NEXTGEN BENEFITS

Investment, equipment and technology development/deployment are critical to delivering the benefits that NextGen promises. But they are not the only critical factors. The operational, environmental and economic benefits of NextGen can still be lost, and the investment in equipment and technology wasted, if other important challenges are not met head-on by the FAA. It is essential that each FAA organization executes its NextGen responsibilities in a timely fashion and that they all work together pursuant to a coordinated and unified strategy that prioritizes NextGen implementation. These challenges include:

- ***Promptly complete airspace redesign***. FAA has underway a major overhaul of the NY/NJ/PHL airspace that is essential to improving the flow of traffic into, out of and through these metropolitan areas. It will significantly improve operational efficiency in this region and the entire NAS. Because it changes noise patterns, however, it has met stiff local political and public opposition and is the subject of multiple legal challenges. It is imperative that FAA push through these political and legal challenges and stay the course. And it must stay the course as it implements airspace redesign initiatives elsewhere in the NAS, such as Chicago and the West Coast corridor.

- ***Develop new separation standards and approve new operations procedures***. For NextGen to deliver new capacity and efficiency, the FAA must develop new, reduced separation standards that take advantage of NextGen technological capabilities. In addition to separation standards, FAA also must establish criteria for the development and approval of new operations procedures such as simultaneous operations on closely spaced parallel runways, curved approaches, multiple precise departure paths, continuous descent approaches and optimized profile descents. Bureaucratic roadblocks and turf battles must be avoided. New standards and procedures must be viewed as going hand in glove with new technology.

- ***Controller acceptance and implementation of new procedures***. FAA must partner with its controller workforce and make them part of the NextGen process. If controllers to not accept new separation standards and utilize new precision operations procedures, then the equipment investment for NextGen will be wasted. FAA must find a way to resolve the contract dispute with the controllers, which to date has served as a roadblock to controller input into NextGen development.

- ***Maintain a sufficient constellation of satellites to meet FAA safety standards***. There is an assumption that the GPS satellite constellation servicing NextGen surveillance, navigation and communications functions will be adequate to meet stringent FAA safety standards. However, in some models, the minimum number of satellites FAA assumes for its performance-level safety analysis is not sufficient. FAA and the Department of Defense must come to agreement on the minimum satellites needed for NextGen to provide the performance level required by FAA safety criteria, and Congress must provide the necessary funds.

Conclusion

We have arrived at a pivotal moment for U.S. aviation. Industry stakeholders support the FAA NextGen program – an event not to be overlooked – and the FAA has developed a comprehensive implementation plan. The plan's flaw, which delays NextGen benefits for too long, can be overcome by an immediate boost in funding to jump-start equipment deployment on the ground and in the air. We urge the Subcommittee to make the rapid, successful implementation of NextGen happen now.

BIOGRAPHY FOR HOLDEN E. SHANNON

Holden E. Shannon is Senior Vice President of Global Real Estate and Security, a position he has held since August 2004. In this role, he is responsible for developing the airlines' facilities worldwide, including its hubs in Houston, Newark and Cleveland and its headquarters in downtown Houston. Shannon also is responsible for the airline's corporate security and environmental affairs groups. Prior to this position, he was Vice President of Corporate Real Estate and Environmental Affairs for Continental from August 1997 to August 2004.

Shannon joined Continental in January 1995 as Staff Vice President of Properties and Facilities, responsible for overseeing system-wide airport and property development.

Prior to joining the company, Shannon held positions of increasing responsibility at Northwest Airlines, including Director of Corporate Real Estate and Manager of Finance. He also held positions in finance with American Airlines and The First Boston Corporation.

Shannon received his Master of Business Administration from Harvard University. He also graduated from Rice University, *cum laude* with a Bachelor's degree in managerial studies. He serves on the Founding Board of Directors of The Rice Building Institute and on the board of Houston's Lawndale Art Center. Shannon lives in Houston with his wife and two children.

DISCUSSION

QUANTIFYING PRIORITY LEVELS FOR BIOFUELS IN THE AVIATION INDUSTRY

Chairwoman GIFFORDS. Thank you so much. At this point, we are going to begin our first round of questions, and the Chair will begin with herself.

Again, I want to thank all of you for being here and for the Members in attendance. I think you have made a compelling case of the importance of the use of aviation biofuels. Those of us who fly every week, we pay attention and those that don't fly every week but fly occasionally, we realize that getting this right in the future really has a significant impact to all of us, not just those of us in Congress or those of us who pay attention to these issues.

But I guess I would really like to drill down a little bit harder in terms of how high a priority it is for your specific organizations. For example, Mr. Shannon, you said specifically that continuing with the investment of biofuels is a priority. But exactly when does Continental project that it is going to start using biofuels in its revenue operations? And if you could go into a little bit more detail in what type of biofuels you really imagine using.

In terms of your competitors, can you talk about the sense of how biofuels fit into their plans as well. And so for Mr. Glover and Dr. Epstein, how important are biofuels to Boeing and Pratt & Whitney's plans, and what investments are your companies making to actually be able to deploy the technology so that we can, you know, in our generation, in our lifetime, really see this as a mainstream form of fuel. And Dr. Maurice, I know that the FAA is obviously participating in CAAFI, and I liked your graphic and slide. You didn't completely go into it, but it was impressive to see the diverse group of organizations involved. But in terms of specifically what is FAA doing to hasten the adoption of whatever biofuels to really make the most sense for the aviation industry? I mean, you talked about the importance of fuel certification. What specific plans and resource commitments has the FAA made to certify not just the drop-in fuels but also the full range of renewable biofuels that could meet the aviation sector needs?

Also, how long are we talking about? And again, how high a priority is it on a list of everything that is on the FAA's plate?

Finally, Dr. Shin, your testimony discusses the long-term R&D needs to address some of the important unknown-related biofuels. But in terms of the relation to NASA's aeronautics priorities, can you talk about that in terms of the other issues that are facing you and your organization? Why don't we start with Mr. Shannon.

Mr. SHANNON. Thank you. Thanks for the promotion, too. I think self-interest is the key to your question. In other words, if biofuels become an economical force, then I think we would embrace them. We feel very good about the preliminary data from our biofuel test. As someone pointed out, the more biofuel tests there are, the less scary the concept for the public. What is beautiful about this technology is that it has enough horsepower, unlike ethanol. It absolutely does not compete with land that would otherwise be used for crops. You can't eat algae. There is no competition in terms of other demands on the product, and I think as soon as it becomes less than two to three times as expensive as petroleum, I don't think there is going to be an issue because we can add it incrementally with traditional fuels, and we don't have to change our significant 30-, 40-year investment in engines and aircrafts. So I think it can be very soon, possibly as early as five to ten years.

Mr. GLOVER. Thank you. About five years ago, we were complete skeptics. We said there is not enough energy content. We were familiar with ethanol and biodiesel and so on, and you can't produce enough of this and we would have to modify engines, the delivery systems. We were starting to see some changes and things that caught our attention. And when we were looking at the environmental strategy for the whole industry and said, well, we can keep producing more efficient aircraft, we can help improve the operations, the daily operations, but what else can we do? And we really took a critical look at the fuels. We helped get started the CAAFI organization to bring more attention to this and find out what can work, and we became complete converts.

So we invested our intellectual capital and our convening power to work with airlines and engine companies and the FAA and others to bring this together, get the facts on the table and figure out the viability. We think we are largely through the first round of viability, and now we are helping airlines and fuel producers and agricultural interests, try to put together deals that could end up in a commercially offerable product. And we really see the need to accelerate that, and we are looking for assistance from the U.S. Government to find ways to help get over those initial capitalization humps, loan guarantees, and other forms of appropriate encouragement to enable commercialization.

We think there are a few things that are ready now and things that need some more R&D that will come later.

Dr. EPSTEIN. Pratt & Whitney is committed to environmentally responsible propulsion which is our business, and I am speaking as a propulsion guy. Innovation has been the underpinning really of U.S. productivity in the last few decades, and this is an area, as Mr. Glover said, where just a few years ago, what is fuel? You know, it is what we pour in the tanks, what we get out of the tank truck, it has always been the same. And then we have learned with the DOD energy independence effort to certify new fuels how to do it. We worked with the FAA, NASA, and DOD researchers making our engines and test facilities available so they could come and make measurements. And now innovations as—we have done two things. We have reduced the amount of fuel we need to certify down to 250,000 gallons. Now that seems like a lot except a 747 takes about 50,000 gallons to fill up. So it is not all that much, especially compared to the past where we need millions of gallons.

The other is, we are getting very enthusiastic because these are really engineered fuels, and American ingenuity and engineering say they are better fuels. And if you can tell me that my engine will have those fuels in the future, I can make a better commercial and better military engine, one that will be lighter, burn less fuel. So we are very enthusiastic about it. Nevertheless, Pratt & Whitney and United Technologies doesn't intend to be in the fuel business, but we are responsive to our customers, Boeing and the airlines, and we are enthusiastic about it.

Dr. MAURICE. Thank you for your question, Madam Chair. Renewable fuels are very important to the FAA. Environmental stewardship is at the heart of NextGen. We view renewable jet fuels as the game changer that can really significantly reduce CO_2 emissions.

As far as what we are doing to hasten the adoption, there are really two areas that we have the role on. First and foremost is certification and qualification because you could have the best equipment, the producers could be producing the fuels, but they will produce fuels for those people that can use them. So specifically, we have assigned my colleague, Mark Robinson, to lead the efforts to work with ASTM International, and he also leads CAAFI's efforts in this area. So we have assigned the necessary staff to steward the efforts and make sure that they are carried out well.

As far as timing is concerned, as I noted, later on this year we hope to be able to have approval for a 50 percent generic alternative fuel by the F–T, Fisher-Tropsch process. That could be made from any number of feedstocks including biomass. So it would be a renewable fuel.

Looking further into the future at the hydrotreated renewable jet which is the process that was used to make the fuels tested by my colleagues, we look to next year having the results in front of ASTM International to hopefully get that approved at the 50 percent plan and in looking to 2013 to having the 100 percent hydrotreated renewable jet fuel. So I would echo statements of my colleagues, about three to five years that we could see some significant use.

Chairwoman GIFFORDS. Dr. Maurice, is that effort fully funded at this point?

Dr. MAURICE. That effort with advent of the CLEEN program which funds is appropriated for, I believe it is fully funded. And then the second area which we can get the certification right but we have got to make sure that we know the life cycle of greenhouse gases so that we do the right thing. We are investing resources in working with the appropriate stakeholders to make sure that we can measure that right.

Chairwoman GIFFORDS. Okay. Thank you. I know I am running out of time, but I would like to hear from Dr. Shin, so please.

Dr. SHIN. I will try to be brief. As Madam Chair noted, the value that NASA Aeronautics brings to the Nation by conducting cutting-edge, long-term research, we believe that we will continue work with industry and academia in the whole community to bring these advanced technologies for vehicles and operations in certainly the safety area.

So as biofuels is getting more economically viable and if it gets certification and becomes another source of aviation fuels, we will have to consider that in our future technology development. One of the highest priorities within NASA Aeronautics is to protect the environment from aviation and also make future vehicles more fuel efficient.

So if and when biofuels again become commercially viable and also proves all the benefits, then we will consider this as part of the future technology development, not from the standpoint of production of biofuels but application of the biofuels.

Chairwoman GIFFORDS. Thank you, Dr. Shin. The Chair recognizes Mr. Olson.

BIOFUELS CARBON EMISSION REDUCTIONS

Mr. OLSON. Thank you, Madam Chairwoman, and my first question is for Dr. Shin, Dr. Maurice and Dr. Epstein. You touched on this Dr. Epstein in your opening statement, but understanding that the research in biofuel emissions is still in its early stages, do you have a sense yet of the potential reduction in carbon emissions that could be achieved by using biofuels, and if so, what are the biggest unknowns out there?

Dr. EPSTEIN. I think it is important to understand that the carbon that comes out of the tailpipe of the jet engine is exactly the same no matter what the fuel is, whether it is petroleum-based or coal-based or bio-based. The carbon that we save is the front end, whether the carbon is geological, mined out of the ground, or whether it has been recently extracted by plant action. And so in agriculture, we use fuel for planting, for harvesting, for processing the fuel. As Mr. Glover said, we need careful documentation as to how much carbon fuel is used in these processes. But think. These are the same things that society is working on to improve as you go from big, diesel trucks to more efficient trucks, as you can think of even electric powered trucks and tractors. The entire carbon footprint goes down.

So I can see now where for the few fuels that have been studied carefully, the numbers are 40 to 60 percent net carbon savings. In the longer-term, a decade or two, as society moves more toward carbon-free transportation, the jet fuel can come down to very close to zero. We are just recycling solar energy that we collect on our farms.

Mr. OLSON. Thank you very much. Dr. Maurice.

Dr. MAURICE. Right. That is a very good question. Thank you. We have done a lot of work in looking at the life cycle, and I would say there is no single number. I think Dr. Epstein's 40 to 60 percent is probably right about in the middle, but I would hesitate to put a single number because it is still a very probability type of answer. And as far as what the largest uncertainty is land use. When we tried to allocate different numbers to different parts of the process, that is by far the biggest unknown. We are working hard to try to address that.

I might also mention, don't forget the air quality emissions that we are looking at, and that is pretty straightforward because these alternative fuels are naturally lower sulfur so that intuitively leads to less particulates, and depending on the engine power setting, we have seen reductions from 10 to 70 to 80 percent, and that is very attractive. Thank you.

Mr. OLSON. Thank you very much for that answer. And Dr. Shin.

Dr. SHIN. Yes, as Dr. Maurice just mentioned about the low sulfur emission and particulates, we have conducted partnering with Air Force and FAA and a few other partners on DC–8 aircraft that we have at Dryden Research Center. We didn't fly the airplane but on the ground we simulated engine power setting like the airplane flying, and some of the only findings from the test results support what Dr. Epstein and Dr. Maurice indicated. The full test results will be analyzed, and we are planning to have a workshop in the fall so it will be very interesting to find out what kind of benefit we will gain out of this.

But this is a well-controlled test, and it is one data point. So I think nonetheless, it is going to provide a lot of good information.

CAP-AND-TRADE IS THE WRONG ROUTE

Mr. OLSON. Thank you for that answer, Dr. Shin, and Mr. Shannon, one question for you. Given that Continental has been very proactive regarding fuel efficiency and environmental protections, what is your airline's position on how the industry and government should move forward regarding the environment? I mean, do you see it as a cap-and-trade type system as Europe is proposing or something else?

Mr. SHANNON. We really don't see it as a cap-and-trade solution, and the reason why is because we feel that there are lots of opportunities to reduce greenhouse gases that are available to us today that we are not availing ourselves of, besides the hopefulness of alternative fuels. When you cap-and-trade, you are capping something that is commercially important. The airline industry generates a huge amount of GNP, and of course, it is something that all of us love. If you cap flights, you are going to see higher prices, you are going to see more limited travel.

One of the things we would suggest is encouraging airlines that have old aircraft to think about replacing those engines, replacing those aircraft. There probably isn't a need to have 40-year airplanes flying around. We have really clean airplanes available.

The second thing is that we could do things like modernizing air traffic control. That alone again is 12 percent lower fuel burn. It is not a small number.

And then finally, we do see that there are lots of opportunities to promote fuels like what we have seen in the last year successfully piloted. So we are here because of our hope that this technology will provide a solution that does not force you and the economy to choose between aviation, commerce and greenhouse gases and the environment.

Mr. OLSON. Thank you very much, Mr. Shannon. I yield back my time.

Chairwoman GIFFORDS. Thank you, Mr. Olson. The Chair recognizes Ms. Edwards.

INCENTIVES TO ENCOURAGE ALTERNATIVE FUELS IN THE AVIATION INDUSTRY

Ms. EDWARDS. Thank you, Madam Chairwoman, and thank you to the panelists this morning. I live in the 4th Congressional District in Maryland which is just outside of the District of Columbia, and I happen to live along the Potomac River and you know, get to experience the planes flying over all the way up the river, coming back again, and dumping fuel and particulates all along our baseball fields, soccer fields, elementary schools. And so this is a really important issue for us in my Congressional district and our community and I think largely for the environment—you know, Mr. Shannon, I almost left and then I heard the end of your testimony and decided to stay because you said in your testimony, you talked about cap-and-trade not being a way to go for the industry. There are alternatives, and I want to follow along the lines of Mr. Olson's questioning because I wonder, you are suggesting that there are sort of voluntary things that the industry could do that would move us along the way toward fuel efficiency and using alternative fuels, and yet we are not very far from peak carbon emissions around the world in what, 2015. And so I am wondering, you know, from a policy making perspective, what kinds of incentives can we encourage for the industry because if it is not something that says, you know, you got to get there and make the investment, I think that we are going to get to 2015 and we are not going to be frankly that much farther along than we are now. And so it is a little frustrating that although your airline may be doing the right things, we can't just depend on volunteerism alone to get us to lower our carbon emissions.

Mr. SHANNON. It seems like a really intelligent question, but I don't want to give you a glib answer. Continental really has made it sort of part of our value system to have a clean airline, but I am telling you, I personally feel that self-interest is a huge motivator. And we didn't start off in the early '90s saying we want to be green. Our awareness was raised along with the population's awareness. We were motivated to reduce fuel consumption, pure and simple. That turned into a green philosophy, and we have embraced it. In lots of ways, it may not be economical in the short-term. I think helping us as an industry create affordable alternatives to petroleum is extremely important to traditional fossil fuels. That singularly will help us. We had a wake-up call this last year. I mean, we really did. We realized that cheap oil, traditional oil, will not last forever. That is a huge motivator. And that day, we don't know when that day will change again. Today fuel is relatively more affordable. That is a short-term thing, and we are very motivated to get out of this pinch.

So I personally feel encouraging us as an industry to set fuel efficiency standards, again, we have done a lot as an industry, not just as an airline, but also supporting this effort is one of those things.

Ms. EDWARDS. Do any of our other panelists have a comment?

Dr. EPSTEIN. One thing that is important is the airline industry is extremely capital-intensive. New airplanes cost $100 million or more, and a concern of the industry is that regulations, taxes, carbon trading end up removing money from the aviation system that the airlines need to upgrade their equipment. So how do you reduce the emissions in the short run? The answer is, just as Continental has said, you replace your existing older aircraft, and aircraft work for 30, 40, 50 years. With new airplanes, you need new capital to do that. So Congress has to consider how do you capture any revenue that comes out of regulatory actions in a way that feeds back into the aviation system. Funding air traffic control upgrades, tax credits, investment tax credits for equipment, funding for NASA for advanced research, it really is a system that is starved for funding now. Of course, everybody in the United States is starved for funding now, but the point is, there shouldn't be extraction from the aviation system into other uses if we want to make progress in reducing our impact on local communities and the planet.

Ms. EDWARDS. Thank you, Madam Chairwoman. And I would just say, I can appreciate the industry wanting to move forward without those kind of regulations. My real question is just how do we get there and for those who are not moving in a direction of a greener, more efficient airline, what do we do to incentivize and encourage that? Thank you, Madam Chairwoman.

Chairwoman GIFFORDS. Thank you, Ms. Edwards. Good discussion. Let me just remind the Committee Members and our panelists that this is a discussion today on biofuels and aviation. This is not a big discussion on cap-and-trade or issues that this subcommittee is not faced with. I mean, we have a unique opportunity to hear from five experts on what is happening in terms of biofuel development, and I just want to make sure we don't stray too far. We are going to have a lot of time to discuss other issues, but today if we could just focus on the hearing topic, I would appreciate that.

Mr. Rohrabacher.

REDUCING AVIATION PARTICULATES TO CURB POLLUTION

Mr. ROHRABACHER. You notice she said that right before I got up. First of all, let me commend the Chair. This has been a very valuable hearing, and I think you put together a good panel for us, and I have learned a lot. I would, however, on another issue which has been the undercurrent of all this testimony is that somehow carbon footprints are affecting our climate. Just for the record at the hearing, I have quotes from major prominent scientists from throughout the world suggesting that CO_2 has nothing to do with climate change, especially global warming, considering that now it used to be global warming and because it is no longer warming, now they call it climate change. So anyway, for the record, I would like to put that in at this point.[*See Appendix 2: Additional Material for the Record.]*

Let me say you do not have to be someone concerned about what I consider to be a bogus issue which is global warming, now climate change, to be very concerned about the health-related problems that come with the internal combustion engine and jet engines and also to be concerned about the fuel that would be available to our society to make sure that we can have a modern society and meet our needs.

So with that, I am very concerned about what you have said, although I disagree with the carbon footprint talk. Let me ask this question. In terms of biofuels, you have made it clear about the carbon footprint. What about pollutants such as NO_X? If we were going to with biofuels for jet airlines, would we then have more NO_X and pollutants that hurt human health or would we have fewer of those pollutants entering the atmosphere? And particulates as well, right.

Dr. EPSTEIN. NASA researchers and DOD researchers spent a lot of time at Pratt & Whitney measuring the effects on engines. For current engines we expect no impact on NO_X at all, that is, you get the same NO_X out whether it is a biofuel or petroleum fuel. If the biofuel is more than 50 percent biofuel, then we expect a reduction—we don't expect, we have measured reductions, significant reductions, in regulated particulates coming out of the engines. So these are both local air quality improvements.

In terms of advanced engines, if we knew we had biofuels, we could probably design them to reduce the NO_X a little. The problem is that it is tough to do that and have the capability of pouring in any fuel that is available that is important for assuring the fuel supply for the country.

I would also point out——

Mr. ROHRABACHER. Biofuel specifically. Does biofuel reduce NO_X?

Dr. EPSTEIN. Biofuel has no effect. It doesn't make it better, it doesn't make it worse.

Mr. ROHRABACHER. Okay. Good. Is that what you found?

Mr. SHANNON. I am going to defer to more knowledgeable people on the panel. Our preliminary data suggests it might go down a little bit but not significantly.

Mr. ROHRABACHER. Okay. Let me just note. I do come from Southern California. We have these airplanes coming in all the time. We are very concerned about the pollutants that are coming out of the airplanes, and I think that what you have suggested today in terms of the efficiency of the engines that we have heard about today and the amount of pollutants that your airline has been able to take out, you should be commended for that. I am sorry that our colleague has left who wanted to know maybe how to encourage people to invest in new engines that would bring down the pollution level. Maybe we should—and here is the question. Are the depreciation schedules for the purchase of new engines, what are the depreciation schedules that we have? If we changed that, I am not sure what it is. That is why I am asking essentially Pratt & Whitney and Continental. Are we now encouraged to buy new engines and to invest in these things that would be more efficient and cleaner or could we change that depreciation schedule to give us more of an incentive to do that?

Mr. SHANNON. From a corporate side, I think it has more to do with cash investment. Cash is king in this economy, and I don't think it would materially change our profile. We are just very motivated to get our long-term cost down, not just P&L costs but our real cash-out costs.

Mr. ROHRABACHER. How long does it take you to write down the new engine or a new plane?

Mr. SHANNON. You know, I would have to get back to you. I am thinking that somewhere in the 10-, 15-year timeframe because a lot of that will depend upon the obsolescence of the technology, whereas an airplane itself might have a longer life cycle.

Mr. ROHRABACHER. I am just talking about the tax law now. Pratt & Whitney, how long is it going to take? If somebody is going to buy a new engine from you, how long—if we actually let them write it off the first day, you would have cleaner engines and companies may buy new engines.

Dr. EPSTEIN. A great idea but unfortunately, I am the tech guy, and to answer your question, we need the money men.

Mr. ROHRABACHER. All right.

Dr. EPSTEIN. I am the wrong person.

Mr. ROHRABACHER. Madam Chairman, let me just note that depreciation schedules, tax policy, does impact on these decisions, and if we can change the tax law through depreciation schedules in a way to get people to buy newer jets quicker, it is much better, much more effective as we have heard from Mr. Shannon than to have some other regulatory pressure being put on them. That is the profit incentive you were talking about. Thank you very much, Madam Chairman.

Chairwoman GIFFORDS. Thank you, Mr. Rohrabacher. I would like to welcome Mr. Bilbray to our subcommittee. Also, let me remind folks, we are going to have votes coming up pretty soon. Mr. Bilbray.

REDUCING REAL CARBON EMISSIONS

Mr. BILBRAY. Madam Chair, I appreciate you having this hearing as being a sort of a hotbed of biofuel research. San Diego County, we are on top of a lot of stuff. I have to apologize to you, Madam Chair, though. As we talk about mobile sources, this is a very small portion of mobile sources. We need to remember where we are in the global atmosphere of stuff, that mobile sources, including aircraft, heavy trucks, and everything else, constitute 28 percent of total emissions in this country, 28 percent, while electric generation constitutes 35 percent. And of that electric generation, 22 percent of electric generation is zero-emission generation, has no impact on the climate. So when we talk about these things, we got to remember, we are looking at research to reduce 28 percent of the emissions, and with technology, we may be able to do that, when today as we sit here we have the technology to reduce 100 percent of that 35 percent of stationary sources for the generation of electricity. And I want to say that because as we sit in this room, the Federal Government is still buying dirty coal to generate electricity for this facility, and I hope we can work together to avoid that. So I want to say to those of you who are in aviation, we have a lot in Washington to do to set an example for you, rather than just mandate, set an example.

Let me just throw one thing out. Somebody brought up ethanol. What would happen to you if we mandated 10 percent of your fuel has to be ethanol, like we have done to the auto industry?

Mr. GLOVER. Ethanol would not work on any of the current airplanes without very significant modifications. It would not fit into the fuel distribution system, and you couldn't fly as far on the same amount of fuel.

Mr. BILBRAY. Because it doesn't constitute the BTUs per gallon that you have with the other.

Mr. GLOVER. It doesn't have the energy——

Mr. BILBRAY. We always say about a gallon-and-a-half of ethanol to match a gallon of traditional gasoline, let alone the fuel you are having.

Mr. GLOVER. It is the energy content as well as the compatibility. It is incompatible with some of the materials.

SUBSIZING ALGAE AS A BIOFUEL

Mr. BILBRAY. And I appreciate that. It is incompatible with a lot of automobile operations, too. That is why we can't ship it through our pipelines, we can't use it for refinery, that is why California has determined that it has no environmental benefit, ARB. We are kind of experts in this.

I bring that out because we got to go back to what we are doing with a lot of this. In fact, when we talk about emissions, Madam Chair, because ethanol, it takes a gallon and a half to match gasoline, the emissions are per gallon, not per BTU. And that dirty little secret is that we are mandating a use of a product that claims to be environmentally friendly, but in fact, because of its lack of power actually is a hidden pollutant problem. I know it is not popular here to bring up, but I want to bring this up. On the positive side of it, though—let me say the negative, too, we give ethanol a tax subsidy but we don't give algae fuel a tax subsidy. Does that sound logical to you guys? Go ahead.

Mr. GLOVER. I think we need to—I appreciate if there were supportive policy in place for this different kind of fuel we are talking about here. It is not ethanol, it is this hydrotreated renewable jet. It is a different set of molecules. It has the higher energy content, it has the compatibility. Algae is one of the sources we are working on, very promising. We have a little more work to do, but there are some other things that are ready now, and with some supportive policy in place, I think we can make it affordable, make it available to Mr. Shannon.

Mr. BILBRAY. All right. Now, let me clarify. I totally understand why Members of Congress from corn-growing states have pushed this. I totally understand that. What I don't understand is why the rest of us who care about the big picture and the environment haven't pushed back to balance it out.

I would have to ask Dr. Maurice is it, in your position with the FAA, have you met with representatives of the Defense Department regarding an initiative to test and certify synthetic fuels including biomass jet fuels?

Dr. MAURICE. Thank you for that question. Absolutely, within the Commercial Aviation Alternative Fuels Initiative, one of our collaborators is the Department of Defense, and we share data and collaborate on tests. I might also add that I started my career at the Air Force research lab and the fields lab so I also have personal relationships with those folks. So we are working very closely together.

Mr. BILBRAY. And does the other services besides the Air Force, are they working with things like algae or biomass fuels?

Dr. MAURICE. The others, we do work with some of the other services, but the Air Force is by far the biggest user. So they seem to be putting forth the most effort.

Mr. BILBRAY. I appreciate it. Madam Chair, I appreciate the chance. I think when we talk about these technologies, I just want to let you know that the bad news on this is the fact that industry is looking for places it can build the facility and get licensed, and the sad thing about it is where you have got San Diego County where we have all this research, this breakthrough, sadly they have got to go to New Mexico because in California, the government will not permit the construction of the facilities to make the fuel within the decade. And we really need to put pressure on our colleagues in government to help this move along.

So I yield back and I appreciate the chance.

EXECUTIVE BRANCH COORDINATION OF BIOFUELS R&D

Chairwoman GIFFORDS. Thank you, Mr. Bilbray. You are welcome to our subcommittee any time. Come back. We still have some time, so I would really like to kind of drill down again, and I would like to use the analogy of building a house. If you are the main contractor, you have got to figure out whether or not your electrician is moving in the right direction, you have got your plumber, of course, you have got the carpenters, you have got a schedule to meet. So in a way, you have got to make sure that everything is aligned. So just starting with Dr. Maurice, how does CAAFI determine whether alternative R&D initiatives by government entities and the private sector are properly lining up? And given that CAAFI has no budgetary or management authority, how is it that you are going to ensure that the various initiatives get aligned if they aren't?

And for Dr. Maurice and Dr. Shin, who exactly in the executive branch do FAA, NASA DOD, DARPA, and DOE report to each as an agency to determine what efforts are under way right now or are being undertaken in the area of aviation biofuels? And is there an individual organization that has the responsibility for the Nation's aviation biofuels activities at this point? And if so, who? And if not, are there any plans to create such a leadership position?

Dr. MAURICE. Thank you, Madam Chair. I will start with the question on the building a house analogy which is actually a very good analogy for CAAFI because that is the approach that we have taken in looking at all of the various elements. As far as how CAAFI goes about ensuring that we are all moving in the right direction, there are two tools that we use. One is the set of roadmaps in each of the areas to make sure that we can figure out where we want to be and what all the activities need to be to get there. The second tool that we just recently developed in January is this fuel readiness level scale which was really patterned after the technology readiness level to really assess where various alternative fuels including biojet renewable fuels are within the scale so that we can figure out what it is that we need to do to move them forward.

You are absolutely right about CAAFI not having the mandate and budgetary authority, but I would go back to what Mr. Shannon said, the term self-interest, and I think all of us within CAAFI are very, very motivated to make this happen. And it is within our self-interest to make sure that things move forward. For example, in the certification area, we need data, and our colleagues, Mr. Glover and Mr. Shannon, as they have moved forward planning their flight tests, have collaborated with us so we can define what is it that you really need so we can collect that data. So I believe we are following your analogy of building the house and making sure we have all of the subcontractors moving in the right direction.

As far as your second question of coordination, in his testimony, Dr. Shin referred to the National Aeronautics R&D plan related to infrastructure. Within that plan, there is an energy and environment section which I happen to be one of the co-chairs for. And that again is led by OSTP, by the Office of Science and Technology Policy, and we have used that mechanism to look at the efforts at the broad level. As far as is there one particular entity that has charge of everything, I am not aware of such a thing.

Dr. SHIN. I think as important topic as this biofuel is for the implication or potential for the aviation sector, I would like to use another metaphor or analogy that we have been working within government for bringing this revolutionary air transportation system. Some of the witnesses even noted that Next Generation air transportation system effort. I use that as somewhat of an analogy for the magnitude and scope of this kind of emerging technology in involving not only government and private sector and also academia to create innovative research. I think we can use the committee that Dr. Maurice just mentioned under OSTP as a venue to facilitate that kind of government-wide coordination and collaboration. And that subcommittee has been in place for a good three years, and it has produced a first-ever aeronautics R&D policy and also a subsequent plan. In that plan, as Dr. Maurice noted, there is a whole section devoted to energy and environment. So I think that is a starting point, could be a starting point, to provide better government coordination.

Chairwoman GIFFORDS. Thank you, Dr. Shin. Mr. Olson.

POSSIBLE UNINTENDED CONSEQUENCES OF BIOFUELS PRODUCTION

Mr. OLSON. Thank you again, Madam Chairwoman, and I will be brief as we hear the bells ringing. Just one more question for you, Dr. Maurice. I know you are popular today, but I know the FAA and the EPA are working to accurately measure the emissions data associated with the biofuels production use. And I am just curious if you have seen any downsides, start to see any downsides, some unanticipated results of the research that they might emit a greater form of one pollutant or an altogether new type of pollutant compared to conventional jet fuels?

Dr. MAURICE. Thank you, Mr. Olson, for that question. We certainly are looking at all potential contingencies. As far as the tailpipe emissions, we really do not see anything because the fuels are drop-in, other than that change in particulate matter. As far as life cycle emissions, pretty quickly we determined that any competition with food sources or anything that might lead to perhaps using rainforest land and such is not a path that we would pursue, and very quickly CAAFI together and all of us individually came up with this concept that we would go after inedible materials and materials that would not compete with food sources or encourage that sort of land use.

So that has been the preliminary work, and we are continuing to look at all possibilities. Thank you so much.

Mr. OLSON. Thank you very much for that answer. Anybody else like to comment on the question? Mr. Glover.

Mr. GLOVER. I would actually like to comment on something that hasn't come up, if you will indulge me.

Mr. OLSON. Fire away.

Mr. GLOVER. This is a new industry. This is jobs. This is not only technology and environment but it is also jobs. It is an opportunity that I hope you recognize and can help us go down the path. We are trying to do our best, and we would sure like to work with everyone to get it done.

Mr. OLSON. Thank you very much for that answer. I yield back my time, Madam Chairwoman.

WHERE IS THE U.S. IN COMPARISON TO EUROPE ON BIOFUELS?

Chairwoman GIFFORDS. Thank you, Mr. Olson. Following up on what Mr. Glover said, I agree it is jobs but it is also an ability for us to inspire that next generation. We spend a lot of time talking about space in this subcommittee and in this room, and kids are much more in tune with what is happening with the environment, what is happening with the planet. They want to do things in a new and innovative way. And so I think in terms of some of the work that we do to try to get more kids active in STEM education areas, this is a really key way.

I just would like to close with one question which is a broad, international question. I know that the European community recently awarded a contract to ONERA which is a French aerospace research office to look at all aspects of alternative fuels for aviation. I also know that there is a plan by 2012 to be perhaps taxing our airlines as they fly into Europe, and I know that what we would do in the United States is one thing. Obviously, those that would have international businesses have another area that they have to focus on. So I am just curious if our witnesses would like to talk about the scope and comprehensiveness of the European community's research plan and particularly in relation to ours.

Dr. EPSTEIN. For the first 80 years or so of aviation, there was a partnership between government and industry, investing in research where the government and industry shared research investments and then industry took to investing in exciting new aerospace products.

To a large degree, that has eroded in this country over the last decade or 15 years, and our products are so long that although we have a brand-new engine that we are just introducing, it is really the fruits of a NASA investment in the early '80s and early '90s. What I see now is that the preponderance of aerospace investment is moving from the United States to Europe. And so now aerospace is the largest manufactured export of the United States. It may not be in the future. We need the investment, we need the excitement to bring young people. I see as you pointed out inspiring young people—I find it is very inspiring for our older people. It has been astonishing how people come up to me and say, you know, I am really glad to see the company is doing things to make the planet better and to help do the green. I think the Nation has to consider its balance of investments in terms of research and technology, and aerospace frankly has been languishing and we may have a problem going forward in the future.

The one other thing I would add is for emissions and climate, the world and the industry has been very well-served by ICAO, the International Civil Aviation Organization, which sets standards for noise and for emissions. The FAA is the representative of the United States. For manufacturers, it tells us what is coming, it lets us plan our products, lets us invest in research so we can meet upcoming requirements. I think it is very important that we not let other countries impose standards but work together with these international bodies in a consortium to understand where we are going and continue to allow us to do this long-term planning. Thank you.

Dr. MAURICE. Thank you. If I could just specifically talk about where we are at with respect to Europe on the subject today, biofuels, I think that is an area that we had, and that particular consortium that you noted actually came to us to learn from how we had formed CAAFI. So I think that that is an area in which we do have leadership, and I fully agree with you on the inspiration as 25 years ago I came to work in this industry to work on alternative fuels for aviation and hopefully will get it right this time. Thank you so much.

Chairwoman GIFFORDS. Thank you. Before bringing this hearing to a close, I want to thank our witnesses for being here today. I want to thank our Members and for Mr. Olson. I think it was a good discussion. The record will remain open for two weeks for additional statements from the Members and for answers to any of the follow-up questions that Subcommittee Members may ask of the witnesses. The witnesses are excused, and this hearing is now adjourned. Thank you so much.

[Whereupon, at 11:28 a.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, National Aeronautics and Space Administration (NASA)

Questions submitted by Chairwoman Gabrielle Giffords

Q1. I understand that NASA primarily focuses on mid- to long-tern research in aeronautics. If biofuels can be ready for use in a few years, is there any role for NASA in this area? If so, what is it? How would you go about developing an appropriate R&D plan to address the issues you have highlighted in your testimony?

If a usable quantity of biofuels becomes available for aviation use in a few years, for a near-term, NASA could participate in community's effort in assessing the safety and performance of their use in aircraft.

A1. The process used to develop an appropriate research and development (R&D) plan would be similar to the process currently in place to develop existing R&D plans. In brief, NASA begins by working with parties concerned with the technology being considered and our partners from other government agencies, industry and academia to define objectives, understand the key issues and challenges, develop estimates of the time and resources needed to address those challenges, identify the appropriate roles for NASA and its partners that make the best use of the capabilities possessed by each organization, and determine the expected outcome based on the resources and talents that will be employed. NASA has participated in Commercial Aviation Alternative Fuels Initiative (CAAFI) roadmapping exercises for fuel property testing and component and engine testing to begin this process for biofuels, and we will continue that involvement.

Q2. In assessing federal efforts with regards to achieving the goal of enabling new aviation fuels to ensure a secure and stable supply, the Technical Appendix to the National Plan for Aeronautics R&D says:

"DOD efforts to develop new alternative aviation fuels are making progress, but civil efforts, though making some progress, are not adequate to meet both the near- and the combined mid- and far-term objectives in a timely manner without either reconsidering the objectives or the current allocation of resources."

What more should the Federal Government be doing in this area?

A2. The chief impediments to large-scale production are economic and environmental, and these barriers are being addressed by the Departments of Defense (DOD) (Federal Aviation Administration (FAA) and Energy (DOE) as well as private energy sector R&D. NASA has supported this activity with laboratory studies of Fisher-Tropsch (F–T) chemistry to improve jet fuel yield.

Q3. Has NASA's research on engine exhaust emissions using alternative fuels given you sufficient confidence that these fuels will enable significant reductions of harmful emissions such as sulfur and particulates? What additional research, if any, do you think is needed?

A3. NASA evaluations of alternative fuel emissions so far have been limited to F–T fuels produced from natural gas or coal. NASA has found that pure F–T fuels and F–T fuel blends (F–T blended with conventional JP–8 fuel) emit less sulfur oxides and significantly less particulates than conventional fuels because the F–T fuels contained no sulfur or aromatics (though sulfur and aromatics are present when pure F–T fuels are blended with conventional JP–8), and the hydrogen content was higher than conventional jet fuel. Nitrous oxides (NO_X) and CO_2 emissions were very similar to conventional jet fuel, as expected. Some preliminary tests by DOD and FAA do show that biofuels have similar emissions characteristics as F–T fuels.

Fundamental combustion research for these alternative fuels would help improve our basic understanding of the physical phenomena involved including fuel atomization, vaporization, and combustion chemistry. This could help enable development of combustion systems with reduced emissions that will use these fuels in the future. Additional research also could be conducted to ensure durability and reliability of engines when operated on drop-in alternative fuels and blends.

Q4. The Technical Appendix to the National Plan for Aeronautics Research and Development and Related Infrastructure *released last December identified two areas of increasing importance and high uncertainty relating to air quality. The first area is fine particulate matter, and the second is the potential for aviation* *to emit hazardous air pollutants. The document says that there are currently no standardized test procedures for particulate matter from aircraft engines. Why are these two areas so problematic and will NASA be involved in establishing standardized test procedures?*

A4. The combustion process produces solid and volatile aerosol particulates which are emitted into the atmosphere through the engine exhaust. These particles are quite numerous and extremely small, with an average size of less than 100 nanometers. Sampling and measuring these is extremely difficult because effects of the sampling probe, sampling lines, operating conditions, different measurement instruments, etc., can have dramatic effects on the results. The SAE–E–31 Aircraft Exhaust Emissions Measurement Committee is in the process of developing measurement standards for particulates which is very difficult due to these issues. They have published a document on measurement techniques for measuring non-volatile exhaust particulates. NASA (along with DOD, FAA and the Environmental Protection Agency (EPA) is an active member of this subcommittee and currently performing research to address some of these issues.

Q5. As you know, the Air Force has set a goal of certifying all its aircraft to run on synthetic fuel by 2010, and having those flying domestically do so on 50 percent synthetic fuels by 2016. What has NASA learned from its collaboration with the Air Force on alternative fuel research? Is there an opportunity for the Air Force to benefit from civil aviation research into biofuels?

A5. NASA has benefited from collaborating with the Air Force on alternative fuel research. NASA has purchased two Fischer-Tropsch fuels in conjunction with the Air Force for our research activities. NASA has also collaborated with the Air Force in exchanging fuel property data for a number of alternative fuels. The Air Force has provided data to NASA on their engine emissions measurements using alternative fuels. NASA and the Air Force recently collaborated on emissions testing using a Pratt and Whitney 308 engine with F–T fuel and the Aviation Alternative Fuel Emissions Experiment using a NASA DC–8 aircraft with two F–T fuels. NASA also has teamed with the Air Force for combustion flame tube testing at the Air Force Research Laboratory (AFRL) using alternative fuels.

NASA's fundamental combustion research can directly benefit the Air Force. As an example, NASA work on alternative fuel reaction kinetics was recently provided to the Air Force. NASA's work on developing future low emissions combustion concepts with biofuels could directly benefit the Air Force because some of their aircraft will have commercial engines or derivatives of commercial engines. The Air Force can also benefit from NASA research on biofuels. They are working with NASA to identify algae producers to provide algae oil for their research.

Questions submitted by Representative Pete Olson

Biofuels Feedstock

Q1. What are the relative advantages and disadvantages of the feedstocks—jatropha, camelina, and algae discussed at the Subcommittee hearing, especially with regard to land use, water use, processing, and production rates?

A1. Camelina has recently become of interest because it is cold tolerant, grows on marginal land, and can produce approximately 100 gallons per acre of feedstock oil. It can also be used as food crop. Jatropha grows in tropical or semitropical climates on marginal lands and can produce approximately 200 gallons per acre of feedstock oil. It is not a food crop and some papers discuss issues with toxicity. Jatropha is a bushy plant or small tree and the fruit is harvested by hand. Algae can be grown in brackish water and has the potential to produce much higher yields of 5,000 gallons per acre or more in wane water but has many issues associated with growth and harvesting. This is an active area of current research and new developments could have an impact on these issues. Limited quantities of jet fuel have been made using Jatropha, camelina, and algae oil.

Certification vs. Research

Q2. Dr. Maurice stated that some forms of biofuels may be certified "as early as the end of 2010." Dr. Shin, you stated that NASA "believes long-term, foundational research on understanding of fuel processing, combustor and engine performance, durability of engine components and emission characteristics will be required for application of second generation biofuels in aviation." Are these two statements in conflict with each other? How should they be reconciled?

A2. Biojet fuel certification is a procedure to make sure fuel will meet stringent requirements for current engines, meaning no engine modification is required. The statements are not contradictory. Certification of biofuel blends (as stated by Dr. Maurice) by 2010 does not negate the need to perform long-term, foundational research on understanding of fuel processing, combustor and engine performance, durability of engine components and emission characteristics. It is unlikely that biofuels will be produced from a single feedstock source or processing technology, which may result in some variations in fuel properties. Changing fuel composition can have dramatic effects on fuel atomization, vaporization and combustion chemistry, which in turn will affect the emissions and performance of the combustion system. Fundamental combustion research is therefore required to fully understand the effects of additional evolving fuels on combustor performance and emissions. NASA is also performing research and working with engine companies and universities to develop fuel flexible combustors that reduce NO_X, CO, unburned hydrocarbons, and particulate emissions for future aircraft engines that will be more fuel efficient than the current generation. This is not an easy task and will require the development of new combustor concepts in order to meet these goals. These future combustor concepts may be able to utilize some of the unique properties of these alternative fuels to reduce emissions beyond what can be achieved with current jet fuel.

Hydroprocessed Fuels

Q3. How does hydroprocessing biofuels differ from Fischer-Tropsch, especially with regard to production efficiency, CO_2, and technical maturity? Does one process have a distinct advantage over the other?

A3. Hydroprocessing bio oils to produce jet fuel requires less energy than does the Fischer-Tropsch process with natural gas, coal or biomass as the feedstock because the composition of the bio oil feedstock is much closer to the final desired product. Life cycle CO_2 emissions produced for jet fuel using the Fischer-Tropsch process are higher than conventional petroleum processing but can be reduced using carbon sequestration and including biomass as part of the feedstock, Life cycle CO_2 emissions using hydroprocessing of bio oils are reduced compared to petroleum. This is an active area of research and results are very dependent on the assumptions used in the assessment, particularly land use considerations. Fischer-Tropsch processing to produce jet fuel from coal or natural gas has been demonstrated on a large scale and is currently used by Sasol and Shell. Hydroprocessing has been used by the chemical industry for a number of years but has not been demonstrated on a large scale to convert bio oils into jet fuel.

Engine Performance

Q4. What is the type and scale of research that would be required to fully understand the behavior and performance of biofuels in current-generation turbine engines?

A4. To fully understand the behavior and performance of biofuels in current generation engines would require both engine and flight testing as a minimum. Complete testing of fuel specifications would be required and include separate testing of seal compatibility and fuel lubricity. If any issues are encountered, other component testing might be required such as combustor, fuel nozzle, fuel pump, or other components. Static engine testing on the ground would be required to evaluate emissions and performance issues associated with use of the biofuels. It would also provide an indication of any issues associated with the fuel system including seals or fuel pump wear issues. Assuming enough fuel was available, it could also provide an assessment of reliability and safety issues. Flight testing would probably also be required in order to assess aircraft system effects, transient operation, and altitude relight capability. The FAA-led Continuous Low Energy, Emissions and Noise (CLEEN) program, seeks to support these types of tests. NASA is providing support to the FAA in the planning and execution of the CLEEN program.

Cap-and-Trade

Q5. In aviation markets where carbon emissions schemes may be imposed, is it your expectation that using biofuel blends would be recognized by governments as a carbon offset, thus permitting continued or perhaps increased operational tempos into these markets?

A5. NASA currently does not have any expectations related to offsets.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Lourdes Q. Maurice, Chief Scientific and Technical Advisor, Office of Environment and Energy, Federal Aviation Administration

Questions submitted by Chairwoman Gabrielle Giffords

Q1. In assessing federal efforts with regards to achieving the goal of enabling new aviation fuels to ensure a secure and stable supply, the Technical Appendix to the National Plan for Aeronautics R&D says:

"DOD efforts to develop new alternative aviation fuels are making progress, but civil efforts, though making some progress, are not adequate to meet both the near- and the combined mid- and far-term objectives in a timely manner without either reconsidering the objectives or the current allocation of resources."

What more should the Federal Government be doing in this area?

A1. The role of the Federal Government in enabling new aviation fuels for civil aviation involves three key areas: supporting activities to facilitate the approval of new fuels for use by commercial aircraft, assessing the overall environmental impacts of new fuels, and fostering development of alternative fuel production and infrastructure capability.

The Department of Defense (DOD) efforts to advance alternative fuels were ahead of those of the commercial sector at the time the *Technical Appendix to the National Plan for Aeronautics R&D* was written and published (December 2008). However, more resources have since been focused on the civil sector including investment by private industry in flight demonstrations, the FY 2009 funding of the Continuous Low Energy, Emissions and Noise (CLEEN) program which will seek to advance and demonstrate alternative fuels for commercial aviation with a focus on renewable options, and additional funding by the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and the DOD for emissions measurements and greenhouse gases life cycle analyses. We believe that sufficient federal resources are now in place to meet both the near- and the combined mid- and far-term alternative fuels objectives of the National Plan for Aeronautics R&D.

Q2. Is the alignment of government and industry R&D initiatives you describe in your testimony equivalent to an integrated R&D plan for biofuels in aviation? Is it important to have an integrated plan? If there is an integrated plan, is it being used to determine the funding plans of each of the involved agencies in such R&D, and have all of the agencies formally committed to the implementation of the integrated plan?

A2. The member organizations of the Commercial Aviation Alternative Fuels Initiative (CAAFI) have jointly prepared roadmaps for alternative aviation fuels (including biofuels) research and development (R&D), certification, environmental assessment, and business development efforts. These roadmaps have led to increasing coordination among organizations and have served to guide funding plans of each of the agencies involved, as well as those of the private sector. The CAAFI member federal agencies have not made formal commitments beyond those outlined in the National Plan for Aeronautics R&D. However, although the CAAFI roadmaps are not equivalent to an integrated roadmap or represent funding commitments, they have proven very effective in aligning efforts and the need for a more formal integrated plan is not clear. To date, key tasks identified by CAAFI stakeholders are on or ahead of schedule, and we are confident that our mutual interests will provide the cohesiveness required for success.

Q3. CAAFI lists, among its work to date, "supporting R&D on low carbon fuels sourced from plant oils, algae, and biomass." What is the nature of CAAFI's support? Is it providing any funding or other resource commitments?

A3. CAAFI participants are devoting significant resources in support of low carbon biofuels, although CAAFI does not fund research per se. CAAFI is a coalition of stakeholders that individually sponsor and collectively coordinate research to meet CAAFI's goals. The Boeing. Continental, and CFM International flight test program completed in January 2009 is one example of industry investment in this area. The FAA has funded work in the form of an alternative jet fuel life cycle analysis framework and measurements of alternative fueled engine emissions, and is providing leadership in the development of a new fuel certification process via ASTM International. Another CAAFI sponsor, the Air Transport Association, has signaled its commitment to alternative fuels with the introduction of their alternative fuels principles to support deployment of fuels that meet safety, environmental and economic criteria. CAAFI has also encouraged its members who are interested to submit proposals under the Department of Agriculture program to develop biofuel capacity.

Q4. The Air Transport Association says on its web site:

"In light of this regulatory arrangement and the fact that the specification for Jet A and Jet A–1 fuel is identified in the FAA approval certificate, no other type of fuel can be utilized at this time in the United States. Much work needs to be done before alternative fuels can safely be used in commercial aircraft operation with approval from the FAA."

Do you agree with that statement? If so, what additional work needs to be done and when do you anticipate it will be completed?

A4. We agree, but with the following clarifications. "No other type of fuel" refers to a fuel that does not meet the specification properties of Jet A/A–1 fuel. However, it is possible to use "other types of fuel," or alternative fuels shown to closely meet the specification properties of Jet A/A–1 after sufficient test and analysis work (in addition to the specification properties) show that these fuels are "fit for purpose," (i.e., can be safely used in commercial aircraft operations). We expect seamless integration of these alternative fuels, called "drop-in" fuels, into the distribution system and aircraft operations.

Three classes of drop-in alternative aviation fuels are currently under consideration. Fischer-Tropsch (FT) fuels have completed the fit for purpose evaluation. An industry specification incorporating these fuels is under review, and the ASTM International Aviation Fuels Subcommittee should approve it this year. Hydroprocessed Renewable Jet (HRJ) fuels are currently being evaluated for fit for purpose, and we expect that they will be incorporated into the aviation fuels specification within the next one or two years. Bio-chemically derived fuels are currently in the R&D stage and will follow the HRJ fuels by one to two years.

Q5. Why is a standardized development readiness scale, similar in concept to the Technology Readiness Level scale used by DOD and NASA, needed to track the fuel development, approval and commercialization process? How far away are we from the establishment and global acceptance of such a scale?

A5. CAAFI needed a way to classify and track progress on research, certification, and demonstration activities for alternative fuels. A variety of scales were in use by CAAFI member organizations including the TRL (Technology Readiness Level) used by industry, NASA, and the Air Force, and Manufacturing Readiness Level (MRL) used by the U.S. Air Force and others. Originally, an Airbus CAAFI representative developed a special TRL scale for fuel development, but it was a mixture of research achievements and production development. The CAAFI leadership team felt we needed a new fuel development scale that would allow for parallel fuel research activities and certification activities, as well as clearly show how to transition activities between the CAAFI R&D, certification, environment, and business and economics teams.

The resulting Fuel Readiness Level (FRL) scale shown below includes descriptions customized to fuels research and certification events, and contains specific items of interest to CAAFI members such as required fuel quantities to achieve specific milestones. It also reflects the reality that fuels research, production development, and certification activities may occur at the same time, so a fuel may have different FRL numbers for R&D and certification.

The CAAFI leadership team is currently coordinating the FRL scale with CAAFI member organizations in the U.S. and Europe. The roadmaps and milestone databases developed and maintained by CAAFI use FRL to help organize and track the research and development milestones and the process of developing, certifying, and supplying alternative fuels to commercial aviation.

Questions submitted by Representative Pete Olson

Biofuels Feedstock

Q1. What are the relative advantages and disadvantages of the feedstocks—jatropha, camelina, and algae—discussed at the Subcommittee hearing, especially with regard to land use, water use, processing and production rates?

A1. Jatropha and camelina have an advantage in that they are ready for use now; they can grow in marginal or under-utilized land, do not compete with food sources, and do not require considerable water resources. Camelina is attractive because it can grow as a rotational crop, returning nutrients to the soil between wheat crops. In terms of disadvantages, both jatropha and camelina have relatively low oil yields per acre, and the biomass co-product of jatropha is toxic. Cultivating jatropha and camelina in large enough quantities to meet fuel demands will require vast amounts of acreage and careful land use planning to avoid increased carbon emissions from potential land use changes. There are also concerns about the unintended consequences of introducing a non-native, potentially invasive species to the North American ecosystem.

Algae feedstocks have a number of advantages. It can realize the highest production rate of any known bio-based feedstock, could grow on marginal or desert lands (perhaps even in the ocean), and does not require fresh water. However, it does require sources of salt or brine water. To achieve commercial growth rates, the algae also need a supply of carbon dioxide (CO_2) from an external source, such as a fossil fuel power plant. The largest challenge in terms of energy inputs and environmental impacts lies in separating the water from the algae to enable extracting enable extraction of the oil. There are a large number of research organizations and commercial ventures working to overcome this challenge, but algae is thus far not yet ready for large scale fuel production.

It is important to note that a single feedstock will not provide a solution. We will need to pursue a variety of feedstocks and processes to enable an adequate supply of alternative fuels for aviation.

Certification vs. Research

Q2. Dr. Maurice, you stated that some forms of biofuels may be certified "as early as the end of 2010." Dr. Shin stated that NASA "believes long-term, foundational research on understanding of fuel processing, combustor and engine performance, durability of engine components and emission characteristics will be required for application of second generation biofuels in aviation." Are these two statements in conflict with each other? How should they be reconciled?

A2. I do not believe that there is conflict between these two statements. Dr. Shin's statement generally applies to biofuels at greater than 50 percent blends. At 50 percent or less, Fischer-Tropsch (FT) and hydroprocessed renewable jet HRJ biofuels are consistent with my statement. We forecast approval of FT fuels for use in 2009; these fuels will likely include biomass components. We also forecast approval for use by as early as the end of 2010 of HRJ—the fuel recently flown in the Boeing flight tests—at a 50 percent blend with conventional petroleum derived jet fuel. Industry and the Department of Defense (DOD) are currently collecting data on the properties and performance of these fuels in aircraft and engines that lead us to believe that certification is achievable in the near-term. Both HRJ and other next generation biofuel and processes will likely benefit from long-term research as outlined by Dr. Shin, particularly in the case of use of 100 percent biofuels.

Hydroprocessed fuels

Q3. How does hydroprocessing biofuels differ from Fischer-Tropsch, especially with regard to production efficiency, CO_2 and technical maturity? Does one process have a distinct advantage over the other?

A3. Hydroprocessed biofuels require a renewable oil source (such as that extracted from jatropha, camelina, or algae), while Fischer-Tropsch (FT) synthesis uses natural gas, coal or solid biomass from an energy crop such as miscanthus (a grass) or agriculture or forestry residues/waste. The carbon dioxide (CO_2) emissions and process efficiency of both depend heavily on the choice of feedstock, including approaches to growth and collection. It is possible to capture a large fraction of the emissions from an FT plant with the use of a carbon capture and storage system. FT facilities that do not use carbon capture may need to use a much higher quantity of biomass in order to be environmentally beneficial. Without specific knowledge of the plant configuration and the feedstock, we cannot readily or generically compare the CO_2 emissions and production efficiency of hydroprocessing and FT synthesis. However, our initial computations do show that hydroprocessed fuels generally have lower life cycle emissions than FT fuels.

The technology for FT fuels synthesis is mature and in commercial use. The technology for hydroprocessed biofuels is also technically mature, although not as mature as that of FT processes. Neste Oil is currently constructing several facilities to produce hydroprocessed fuels for the diesel market. In addition, UOP Honeywell and Syntroleum have demonstrated the technology to create hydroprocessed jet fuels.

Engine Performance

Q4. What is the type and scale of research that would be required to fully understand the behavior and performance of biofuels in current-generation turbine engines?

A4. The type and scale of research required to fully understand the performance and behavior of biofuels in current-generation turbine engines will vary depending on the characteristics of the candidate fuel and its similarity to other approved fuels. A complete research program would most likely not go beyond the following elements:

- Initial laboratory evaluation for compliance with the Jet A/A–1 specification properties. This requires about one gallon of the fuel.
- A more in-depth laboratory evaluation of the fuel to determine if it meets the fit for purpose properties of conventionally derived and produced Jet A/A–1 fuel. This would involve about 80 gallons of fuel. We could complete these first two steps in two to four months.
- Materials compatibility testing of the fuel with a defined set of aircraft materials. This would take a small amount of fuel (less than 10 gallons) and take two to four months to complete.
- Engine fuel component testing, engine combustor rig testing, and Auxiliary Power Unit (APU) testing with the candidate fuel. This will require approximately 4000 gallons of the candidate fuel and could take six to eight months to complete.
- Engine ground testing. This will require approximately 200,000 gallons of the fuel and could take up to a year complete.

Note that an alternative fuel may not necessarily have to go through all five of these steps. Industry experts (aircraft, engine and fuel manufacturers) and the Federal Aviation Administration (FAA) may agree that the fuel's characteristics are so similar to petroleum based Jet-A fuel that no further testing is required.

Cap-and-Trade

Q5. In aviation markets where carbon emissions schemes may be imposed, is it your expectation that using biofuel blends would be recognized by governments as carbon offset, thus permitting continued or perhaps increased operational tempos into these markets.

A5. Assuming we can establish a standardized framework for a validated life cycle analysis (LCA), including any land use changes, we expect to document that biofuel blends will have lower life cycle carbon emissions. They could be eligible for prorated carbon offsets based on their audited LCA results. If we can determine that a particular fuel or fuel blend has lower life cycle carbon emissions than those of conventional petroleum derived fuels, it seems prudent to offer credits for the use of such fuels within systems regulating carbon, such as cap-and-trade. The targeting of any credit will depend upon how a scheme is set up and the point of regulation (e.g., fuel producer or user). It is possible that offering such credits would permit continued or increased aviation operations without the need for offsets. Current work by the International Civil Aviation Organization's Group on International Aviation and Climate Change is looking at develop this type of metric for aviation that would adjust for life cycle carbon content of fuels.

Alternative Fuels Research

Q6. Are you aware if the U.S. has previously researched alternative aviation fuel sources, perhaps arising out of past oil embargoes? If so, how would you contrast today's research with previous efforts?

A6. Yes, I am aware that the U.S. had a large government sponsored program in the late 1970s and early 1980s to produce alternative aviation fuels. I started my professional career working on this program. The focus at that time was to develop synthetic fuels from fossil resources, such as shale oil, tar sands and coal, to ensure energy availability and security after the energy crisis of the 1970s. This effort faded, with the dramatic oil glut of the 1980s. I think it instructive with world economic growth showing the largest slowing in nearly 60 years, oil prices still remain twice the levels they were earlier this decade. The return of economic growth will likely reignite pressures on oil prices quickly. In addition, today's alternative fuels research is different in that there are a new set of environmental drivers not present in the previous effort. Air quality and greenhouse gas emissions are now major concerns for aviation, in addition to a secure energy supply and cost. There appears to be fundamental increased need and emphasis that contribute to the relevance and prospects for successful achievement of our current efforts.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Alan H. Epstein, Vice President, Technology and Environment, Pratt & Whitney, United Technologies Corporation

Questions submitted by Chairwoman Gabrielle Giffords

Q1. Your testimony states that we don't need to do any more research before introducing biofuels into civil aviation—that "there are no unanswered scientific questions." Yet, it seems that we need to make sure that we don't wind up starting down the path of planning for the widespread use of a particular aviation 'biofuel' before we understand (1) its impact on emissions, (2) the constraints it may impose on future aircraft technology options, and (3) the impact its production would have on the environment, especially on land use and water requirements. How should we, as a nation, go about picking the best aviation biofuel or biofuels to promote?

A1. My answer, ". . . from the propulsion provider's point of view . . . there are no unanswered scientific questions," was meant to encompass a very narrow set of technical issues concerning the use of specific class of biofuels (synthetic paraffinic kerosene, SPK) in current engines. The message is that there is a near-term, technically viable path to biofuels for commercial aviation.

From the wider points of view of the national endeavor and policy-making perspectives, there is much still to be done to establish the best paths forward—best in the economic, ecological, and technical realms. As suggested in the question, this wider research agenda should include:

- the ecology of biofuels—their impact on land, water, population patterns, wealth generation, and such;
- agricultural/bioengineering approaches to sustainably improving fuel yield per acre;
- establishing a broader technology base for the conversion of biomass into fuels suitable for aviation, technology that can reduce the environmental footprint of the conversion, widen the types of biomass that can be used, and improve the overall economics;
- engine research focused on exploring how the new properties of biofuels and biofuel-conventional fuel mixes can best be exploited in new engine designs to further reduce environmental impact—for example through reduce fuel burn and reductions of particulates and NO_X—and to reduce cost.

Q2. What data is Pratt & Whitney gathering to demonstrate that using biofuels over the long-term will not impact the reliability and maintainability the aircraft engines it produces?

What are the challenges associated with designing an aircraft engine that runs optimally on biofuels? How far are we from seeing such an engine on an airliner?

A2. While we have established that current engines can operate for short periods of time (hours) on the drop-in biofuels tested to date with no apparent deleterious effects, we have no direct engine data to establish the effects of sustained biofuel use on engine reliability and maintainability. This data would come from engine endurance testing which will require several hundred thousand gallons or more of biofuel (about 5–10 million gallons of fuel are burned in a jet engine between overhauls). Such testing is not funded at this time.

Our engines are now optimized to operate on conventional fuel. While preliminary analysis suggests that an engine optimized for biofuel can have fuel economy and emissions superior to that of current engines, little research work has been done to substantiate and exploit the potential advantages of biofuels. Also, research is needed to identify paths toward a dual fuel-optimized engine, one that could realize the best performance with either conventional or biofuels, depending on fuel availability. Without such an investment in engine research, a biofuel-only optimized engine could not go into service until operators could be guaranteed that a significant portion (say 50 percent) of the fuel they purchased was biofuel. This would require biofuel production levels of tens of billions of gallons a year, a level which may be several decades away.

Q3. You indicate in your prepared statement that once biojet fuels are deployed into commercial service, it would be prudent to institute periodic evaluations as engines age. You further state that this is typically done when designs are changed *or new materials are identified. What are some examples of new designs or new materials that have resulted in periodic evaluations? Who funded these tests and evaluations?*

What should be the Federal Government's role helping assess the viability of biofuels for aviation and facilitating their widespread use? Does more need to be done than is currently being done?

A3. When it is clear that a new material or design change is safe but that there may be uncertainty with the economic life, a "controlled service release" can be a useful tool for reducing this uncertainty. In commercial service, the airline and/or original equipment manufacturer (OEM) will inspect the parts in question at relatively frequent intervals to monitor deterioration. One example was a new turbine blade coating that promised longer life and reduced costs to operators. This was first deployed on a single airline with unusually harsh operating conditions. The coated blades were frequently inspected on the wing for several years. Historically, the beneficiaries of such testing pay for it. In commercial service, this would typically be the OEM and/or airline. Since there is no established aviation biofuel industry at this time to provide such funding, government support would help stimulate the aviation biofuel industry by instilling the confidence with biofuels among regulatory authorities, equipment suppliers, airlines.

Q4. Your prepared statement indicates that the growth of the civil aviation biofuel market is dependent on, among other things, authoritative, peer-reviewed quantitative research to establish the carbon footprint of various biofuels and document their sustainable nature. You also say that this will be an ongoing process which should be supported by governments and universities. Can you elaborate on how a consensus on the carbon footprints will be achieved and how long this may take?

A4. Scientific research cycles are several years long—proposals are solicited prepared and evaluated; research performed and documented; papers reviewed and dissimulated at conferences and in journals. A quantitative, scientific consensus on all aspects of aviation biofuels may take several such cycles, depending upon such things as the difficulty and complexity of the topic. Detailed understanding of the carbon footprint and sustainability of specific biofuels has barely started. This is a complex multi-disciplinary topic and relatively few studies have been completed. Some have been influential, for example vectoring the community away from palm oil and pointing out the importance of avoiding deforestation. Some feed stocks are already under study, such as jatrophia and camelina, and initial qualitative work suggests that these can be sustainable when properly managed. Quantitative consensus may reached in as little as three to five years, depending upon the scope of the studies. Expeditious funding of a diverse research community can help both in accelerating such research and in promoting wide dissemination and discussion.

Questions submitted by Representative Pete Olson

Engine Performance

Q1. What is the type and scale of research that would be required to fully understand the behavior and performance of biofuels in current-generation turbine engines?

A1. In the case of a mix of synthetic paraffinic kerosene, SPK, and conventional jet fuel as used in the JAL–P&W–Boeing flight tests, it would be wise to carry out several so-called endurance tests. These serve in the engine development process as accelerated life tests to prove to commercial or military customers that the engine has the durability and life claimed. Assuming availability of the biofuel, such testing could be competed in 12–14 months for $10–20M.

Cap-and-Trade

Q2. In aviation markets where carbon emissions schemes may be imposed, is it your expectation that using biofuel blends would be recognized by governments as a carbon offset, thus permitting continued or perhaps increased operational tempos into these markets?

A2. Short answer: yes.

Longer answer: We would expect that in a carbon regulated world, the regulatory measures put in place by governments would be such as to motivate behaviors that reduced the total carbon released into the atmosphere. So for example, if a biofuel's total carbon footprint was only 50 percent that of a conventional petroleum-derived fuel, the operator using biofuel would need to purchase no more than 50 percent of the carbon credits they would when using conventional fuel. Alternatively, an operator's operations could double without enlarging its carbon footprint. Such market-based flexibility would increase the value of biofuel to airline operators—incentivizing their adoption.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Billy M. Glover, Managing Director of Environment Strategy, Boeing Commercial Airplanes

Questions submitted by Chairwoman Gabrielle Giffords

Q1. What data is Boeing gathering to demonstrate that using biofuels over the long-term will not impact on the reliability and maintainability of the aircraft it produces?

A1. The data already collected indicates that the chemistry of the synthetic paraffinic kerosene (SPK) fuels pose no long-term reliability or maintenance concerns. Engine companies will be evaluating the compiled data over the next few months to determine if any additional testing specifically for the SPKs known as hydrotreated renewable jet fuels (HRJ) must be completed prior to fuel specification approval.

Q2. What should be the Federal Government's role in helping assess the viability of biofuels for aviation and facilitating their widespread use? Does more need to be done than is currently being done?

A2. Federal policy mechanisms should be utilized to assist accelerate research and development that can increase yield of plant oil sources and improve supply chain economics; encourage increased agricultural output of suitable plant oils; help entrepreneurs to scale up and capitalize new production capability; and designate use of sustainable biofuel for use in aviation fuel. As mentioned in my testimony, aviation does not have the range of alternative clean energy sources that other fuel users have, so the opportunity to reduce aviation greenhouse gases by use of sustainable biofuels is a very significant and valuable.

Q3. Boeing has been quoted as having said that it had a hard time finding biofuel suppliers who can produce testable quantities of their product. Do you see this as a temporary annoyance or a growing problem?

A3. This is a temporary situation due to the fact that the technology has evolved at faster pace than the production capacity. Federal policy (see above and written testimony) can help assure that the market development matures.

Q4. Have biofuel producers shown greater interest following recent flight demonstrations? Are there infrastructure and distribution issues that need to be addressed before widespread aviation biofuel use is considered? If so, what are they?

A4. Considerable interest from potential biofuel producers has followed the recent flight demonstrations. A number of scale up and potential commercialization projects are under discussion. Federal support in terms of research grants aimed at scale up, permit streamlining, agricultural education, and loan guarantee programs would be helpful. In addition, a "sense of the Congress" statement indicating the value of directing advanced biofuels towards aviation would be supportive.

Q5. Is additional R&D needed to secure government, airline, and public confidence that biofuels are safe and economically-viable supplements or replacements for jet fuel? Who should conduct this additional R&D?

A5. Additional research and development is needed to improve yield and increase the variety of plants that are/could be suitable for sustainable biofuel for aviation. R&D that can improve harvesting and processing methods is also needed. We are at the beginning of a learning curve and additional research will help to accelerate long-term viability and enable larger scale availability.

Q6. What major challenges do biofuels face in trying to secure modifications to fuel specifications and FAA aircraft certifications? What modifications to the specification of biofuels and aircraft certifications are needed before biofuels can be used in civil aviation?

A6. A new fuel specification for SPK fuels is in development in ASTM. When complete, the new specification will define criteria for fuels from biomass (and other sources) that, from a user point of view, can be treated as "equivalent" to traditional jet fuel from petroleum sources. Once the specification is in place, FAA approval of operation with new SPK fuels will be straight forward. The FAA has played a leadership role to oversee and assure proper development of new specifications, and has strongly supported the work across the industry as embodied in the Commercial

Aviation Fuels Initiative and similar efforts. Continued FAA involvement is required to enable further developments and approval of alternative fuels.

Questions submitted by Representative Pete Olson

Engine Performance

Q1. What is the type and scale of research that would be required to fully understand the behavior and performance of biofuels in current-generation turbine engines?

A1. The validation research for the new Synthetic Paraffinic Kerosene (SPK) fuels has been largely completed. Some additional endurance testing may be needed to build full confidence. Engine companies will be assessing that situation later this year.

Cap-and-Trade

Q2. In aviation markets where carbon emissions schemes may be imposed, is it your expectation that using biofuel blends would be recognized by governments as a carbon offset, thus permitting continued or perhaps increased operational tempos into these markets?

A2. It is my expectation that biofuel blends should and will be recognized as a carbon offset in such schemes. That is one method of ensuring the value is recognized; however a careful construct is required to avoid unintended consequences. For instance, if the means of qualification is ambiguous or overly complex, it could actually deter adoption of low carbon life cycle solutions.

Sustainable Biofuels

Q3. You define 'sustainable biofuels' as having several characteristics, such as using feedstocks that don't compete with food and that don't displace native eco-systems. What regions of the world would be ideal sources of feedstock that would go into the production of biofuels? How do you address the challenge of transporting raw feedstocks to a processing facility, especially for crops grown in lesser developed areas of the world?

A3. Given the variety of potential feedstocks, there is also a wide range of regions where sustainable feedstock might prove viable. Some of those regions are hampered by lack of infrastructure, including transport to market. Also, the agricultural work force may require training to enable economic productivity and yield. I anticipate that business interests and local communities will develop a wide portfolio of solutions. Certainly, government actions to direct appropriate economic, technology and educational attention could help to accelerate beneficial results. Africa and Latin America are two areas where the potential for sustainable biofuels is large, given proper attention.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Holden E. Shannon, Senior Vice President, Global Real Estate and Security, Continental Airlines

Questions submitted by Chairwoman Gabrielle Giffords

Q1. Your prepared statement indicates that Continental would like to see additional long-term materials compatibility testing for system components like o-rings and seals by the manufacturers and the wide dissemination of these results. Who should perform these tests and how would they be funded? Based on your statement, are you concerned that results would not be disseminated widely?

A1. While we were pleased with the test results we have obtained to date, we believe additional long-term materials compatibility testing for system components like o-rings and seals by the aircraft and engine manufacturers would be useful. It is important for manufacturers to disseminate their results through the fuel certification process as well as their normal customer information transfer processes.

WHAT WE SAID IN OUR WRITTEN TESTIMONY: While we were pleased with the test results we have obtained to date, we would like to see additional long-term materials compatibility testing for system components like o-rings and seals by the manufacturers and the wide dissemination of these results. The U.S. organization that certifies jet fuel specifications for use in commercial aircraft is the American Society for Testing and Materials (ASTM) International. They will engage in an extensive data review process before approving new fuel specifications and will decide whether any additional demonstrations are necessary.

Q2. What should be the Federal Government's role in helping assess the viability of biofuels for aviation and facilitating their widespread use? Does more need to be done than is currently being done?

A2. The Federal Government should establish applicable government policies to encourage widespread use of aviation biofuel use through fiscal policy, tax policy, and energy policy. The Federal Government needs to do more to establish polices that will help direct government assistance to the develop biofuels, create infrastructure and distribution systems to airports, and encourage widespread use by airlines.

WHAT WE SAID IN OUR WRITTEN TESTIMONY: While the test itself was highly successful, significant challenges must still be overcome to meet our goal of widespread use of biofuels in aviation.

- A fuel specific standard must be developed which meets key performance and compatibility criteria to ensure safety.
- We will also need to develop a U.S. regulatory requirement mandating the level of quality throughout the supply chain; starting at the refinery all the way through to the airport.
- Federal support will be needed to accelerate the approval and deployment of several alternative aviation fuels that have already been developed and tested.
- Increased funding will be needed for ongoing U.S. military efforts to develop alternative fuels for military jet fleets that will transition to commercial fleets.
- Because of the economic slowdown, investment dollars for already conceived pilot plants and full-scale production plants has dried up. Direct federal support for such infrastructure investments and greater support in the area of research and development, including the feasibility of pipeline use for biofuel transport, may be needed to allow the development plans to proceed.
- In the end, we not only need a stable supply of energy which is independent from foreign oil, but any alternative fuel sources need to be produced in large enough volumes that they are available at an economically viable price. It will take many years to make a robust supply of alternative fuels and a network to deliver it to airports, so continuing our work toward that goal is important now.

Q3. In your opinion, what are the most realistic aviation biofuel options for the near-term? How about for the long-term?

A3. The most optimistic biofuel options will depend on the government and industry support for larger supplies of feedstocks and refiners to spur a cost competitive biofuel. A variety of non-food based plant sources such as camelina, halophytes, or jatropha maybe possible in the near-term, while algae is seen more as a long-term option due to the emerging technology needed to extract the algae oil. Biofuel providers such as UOP will have more information on this topic.

WHAT WE SAID IN OUR WRITTEN TESTIMONY: With the help of the government and continued coordination of the industry, manufacturers and fuel suppliers, we believe that, as long as an alternative fuel is certified for aircraft use, meets the "drop-in" fuel requirement and is available at an economically competitive price as compared to traditional jet fuel, aircraft operators will have the confidence to start using biofuel blends in revenue flights in the next five to 10 years. As the supplies increase in a commercially viable way, we will be able to increase the blend percentage over the years.

Q4. Have biofuel producers shown greater interest following recent flight demonstrations? Are there infrastructure and distribution issues that need to be addressed before widespread biofuel use is considered? If so, what are they?

A4. Yes, biofuel producers have shown increasing interest. Please refer to answer to question #2. Biofuel providers, such as UOP, may have more insight on the infrastructure needs.

WHAT WE SAID IN OUR ORAL TESTIMONY: See #2. While the test itself was highly successful, significant challenges must still be overcome to meet our goal of widespread use of biofuels in aviation.

- A fuel specific standard must be developed which meets key performance and compatibility criteria to ensure safety.
- We need to develop a U.S. regulatory requirement mandating the level of quality throughout the supply chain; starting at the refinery all the way through to the airport.
- Federal support will be needed to accelerate the approval and deployment of several alternative aviation fuels that have already been developed and tested.
- Because of the economic slowdown, investment dollars for already conceived pilot plants and full-scale production plants has dried up. Direct federal support for such infrastructure investments and greater support in the area of research and development, including the feasibility of pipeline use for biofuel transport, may be needed to allow the development plans to proceed.
- In the end, we not only need a stable supply of energy which is independent from foreign oil, but any alternative fuel sources need to be produced in large enough volumes that they are available at an economically viable price. It will take many years to make a robust supply of alternative fuels and a network to deliver it to airports, so continuing our work toward that goal is important now.

With the help of the government and continued coordination of the industry, manufacturers and fuel suppliers, we believe that, as long as an alternative fuel is certified for aircraft use, meets the "drop-in" fuel requirement and is available at an economically competitive price as compared to traditional jet fuel, aircraft operators will have the confidence to start using biofuel blends in revenue flights in the next five to 10 years.

Q5. Some critics minimize the importance of recent flight demonstrations. What is your response to such criticism?

A5. The flight demonstration was a small, but significant step of many toward the development of alternative energy solutions. It was a visible milestone in getting public acceptance of biofuel as a viable fuel for aviation. Our goal in this test was to work with Boeing and CFM to demonstrate that biofuels are safe and we will continue to work with our partners to make sure that safety is our priority.

WHAT WE SAID IN OUR WRITTEN TESTIMONY: Although the flight demonstration was one small step of many toward the development of alternative energy solutions, we were able to help gather important data that is needed for the fuel certification process before the biofuel can be used by the airline industry.

Questions submitted by Representative Pete Olson

Engine Performance

Q1. What is the type and scale of research that would be required to fully understand the behavior and performance of biofuels in current-generation turbine engines?

A1. Continental and the airlines will work together with the aircraft and engine manufacturers to fully understand the performance of biofuels in engines, particularly during the biofuel certification process. To fully understand the scale of the research needed for the engines, we would need to defer to engine manufacturers such as CFM or Pratt & Whitney.

WHAT WE SAID IN OUR WRITTEN TESTIMONY: To this end, Continental was pleased that the fuel property and performance tests showed that the biofuel blend we tested acted just like traditional jet fuel. The multitude of tests performed by Boeing, CFM, UOP, the Air Force Research Lab, as well as other third party labs on the biofuel prior to our flight, all show that the biofuel we used performs just like traditional jet fuel, with no difference in engine or system performance. Continental is working with Boeing and all of its other flight test partners to compile the results of the testing performed on the various biofuels used in other carriers' flight demonstrations.

Cap-and-Trade

Q2. In aviation markets where carbon emissions schemes may be imposed, is it your expectation that using biofuel blends would be recognized by governments as a carbon offset, thus permitting continued or perhaps increased operational tempos into these markets?

A2. The availability of biofuels at economically viable prices would allow our industry to meet increasing strict pollution standards without limiting the transportation industry's growth.

WHAT WE SAID IN OUR ORAL TESTIMONY: Biofuels represents an important option for the airline industry to reduce their already small greenhouse gas footprint. We would be remiss if we did not mention that more focus on the potential, the development and the use of alternative fuels is far more productive than to consider the imposition of some kind of cap and trade policy on the airlines.

As you probably know, government actions which "cap" a company's existing carbon footprint and then "reward" future improvement could have the perverse effect of punishing those who are already diligently reducing our greenhouse gas emissions voluntarily through the purchase of new aircraft. Instead of creating benefits for those who have been unwilling to invest in a clean environment until the government told them to do so, we ought to provide standards which reward excellence and are required to be met by all. Developing a safe and reliable biofuels alternative is an important means of meeting that goal.

Appendix 2:

Additional Material for the Record

Global Warming Quotes

On CO2 . . .

"Believe it or not, Global Warming is not due to human contribution of Carbon Dioxide (CO2). This in fact is the greatest deception in the history of science. We are wasting time, energy and trillions of dollars while creating unnecessary fear and consternation over an issue with no scientific justification. For example, Environment Canada brags about spending $3.7 billion in the last five years dealing with climate change almost all on propaganda trying to defend an indefensible scientific position while at the same time closing weather stations and failing to meet legislated pollution targets."

-Dr. Timothy Ball
Quote from "Global Warming: The Cold, Hard Facts?"
The Canadian Free Press (online) Monday, February 5, 2007
http://www.canadafreepress.com/2007/global-warming020507.htm

"As measured recently by satellite, and published in Science magazine, Greenland is losing .0004% of its ice per year, or 0.4% per century. All modern computer models require nearly 1000 years of carbon concentrations three times what they are today to melt the majority of Greenland's ice. Does anyone seriously believe we will be a fossil-fuel powered society in, say, the year 2500?"
"A small but very vocal band of extremists have been hawking a doomsday scenario, in which Greenland suddenly melts, raising sea levels 12 feet or more by 2100." "...it is repeated everywhere, and its supporters are already claiming that the IPCC" ... "is now wrong because it has toned down its projections of doom and gloom".

-Dr. Patrick Michaels
Quote from an article "Global Warming: So What Else Is New?"
in the San Francisco Chronicle on February 2nd, 2007.

"... in the theory the claim is that if CO2 goes up, temperature will go up. The ice core record of the last 420,000 years shows exactly the opposite. It shows that the temperature changes before the CO2. So the fundamental assumption of the theory is wrong. That means the theory is wrong."

- Dr. Timothy Ball
Quote from the Politics of Global Warming interview in the Pittsburgh Tribune-Review
http://iceagenow.com/Climatologist_Dr_Timothy_Ball.htm

"I DEVOTED six years to carbon accounting, building models for the Australian Greenhouse Office. I am the rocket scientist who wrote the carbon accounting model (FullCAM) that measures Australia's compliance with the Kyoto Protocol, in the land use change and forestry sector. . . . There is no evidence to support the idea that carbon emissions cause significant global warming. None. There is plenty of evidence that global warming has occurred, and theory suggests that carbon emissions should raise temperatures (though by how much is hotly disputed) but there are no observations by anyone that implicate carbon emissions as a significant cause of the recent global warming. . . . The new ice cores show that in the past six global warmings over the past half a million years, the temperature rises occurred on average 800 years before the accompanying rise in atmospheric carbon. Which says something important about which was cause and which was effect."

-Dr David Evans
consultant to the Australian Greenhouse Office from 1999 to 2005.
"No Smoking Hotspot" in *The Australian*
July 18, 2008
http://www.theaustralian.news.com.au/story/0,25197,24036736-7583,00.html

On natural cycles and oceans . . .

"The record-breaking losses in the past couple of years could easily be due to natural fluctuations in the weather, with summer ice increasing again over the next few years,"

-Dr. Vicky Pope
UK Guardian, February 11 2009
http://www.guardian.co.uk/environment/2009/feb/11/climate-change-misleading-claims

"Evidence is presented that the recent worldwide land warming has occurred largely in response to a worldwide warming of the oceans rather than as a direct response to increasing greenhouse gases (GHGs) over land."

-Compo,G.P., and P.D. Sardeshmukh, 2008:
Oceanic influences on recent continental warming.
Climate Dynamics, in press.

"Our study confirms many changes seen in upper Arctic Ocean circulation in the 1990s were mostly decadal in nature, rather than trends caused by global warming."

-James Morison, lead researcher based at the University of Washington's Polar Science Centre Applied Physics Laboratory.
Global warming not to blame for warmer North Pole?
The Register, 15th November 2007
http://www.theregister.co.uk/2007/11/15/ocean_currents_melt_planet/